# Optimising the Use of Antimicrobials: Preparing the Industry for in-water delivery in the short term and improving hygiene and more effectively targeting medication in the longer term

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## Executive summary

Good water supply at pig level is a primary requirement for health and financially rewarding production, but this can often be overlooked. This report is intended to summarise the technical and practical information related to the principles and practices of what 'good supply' means.

The content within this report is based on international standards, published science, and producer advice, coupled with practical experience and knowledge from UK pig production.

It is widely recognised that discrepancies exist between pig units and systems; this means that a prescribed approach in terms of one single system blueprint applicable to all is not possible. Each producer or unit manager must consider their singular circumstances, with the aim of providing sufficient-quality water to each and every pig on their unit.

The following chapters are designed to help producers or unit managers do this and can be used either as a whole process to evaluate the full provision of water and use of this through any production system, or as stand-alone sections to allow more targeted action to be taken on farm.

Key messages from the report show that:

- Clean water is essential for good pig health and efficiency
- Clean water delivery to pigs requires routine actions; it does not happen without input from the producer
- Monitoring water quality and flow rates at the points of delivery is essential practice
- Assessment of water quality falls into three categories:
  - Physical – odour, turbidity, gross contamination
  - Chemical – mineral contaminants (eg sodium, chlorine, nitrogen, sulphates)
  - Microbiological – bacterial/fungal/parasitic (eg *E.Coli*, *Salmonella, Campylobacter*)
- The cost of maintaining good water quality is a beneficial investment; if monitoring shows no need for inputs to improve the water, there is no need for outlay. Conversely, when water quality is shown to be below standard, investment in system improvements including cleaning will give payback
- Good access to water is a prime requirement; providing pigs with the right number of drinkers at the right height, at the best location, and having water at good flow rates
- Survey data shows that most pig units have access to good quality water at point of entry to the farm; however the same data shows that some farms still have room for improvement, with approximately 15 per cent of water samples at the point of delivery to the pigs at either below suggested water quality or water flow rate standards
- The scientific data is clear that poor water quality has a negative impact on pig health and performance, and especially chronic gut/enteric problems
- There are various points of guidance for water quality, and it is suggested that the UK industry might adopt target levels of total viable counts (TVCs) below 1000 per ml and coliforms <100

per 100ml for microbiological standards, with routine testing once any problems have been dealt with

- Guidance on water flow rates is well established and does not need to be changed. The requirement is for flow rates to be tested more systematically on farms, with simple daily checks backed up by occasional measurements
- The mineral content of water supplies should be known. Mains water should not cause problems, although resolution of chronic health issues should at least consider the possibility of contamination and of high mineral content coming from pipework and organic debris within pipework
- The mineral content of farm water supply should be tested at start-up of new systems, or if currently not known. Data from UK farms showed that while *c.*80 per cent of borehole samples were providing good water quality, there were high levels of sulphates and/or iron in the remainder
- The hardware of water delivery systems, the pipework and the drinkers, need maintenance, and can be the source of problems as either contributing to contamination of the water supply, or restricting flow rates, or wasting too much water. All factors increase cost of production
- Good maintenance of water systems requires good staff knowledge and possibly training
- Cleaning regimes for water supplies should be based on need, described by measurement of flow rates and water quality around the unit. Information on cleaning regimes is widely available and needs to be understood to ensure effectiveness
- Cleaning chemicals should be used as directed on manufacturers' guidance, and all staff should be trained in the effective use, storage, and health and safety requirements
- Water systems that have not been cleaned for more than a year may require more care, and attention is drawn to the potential for blockages and component failure. <u>Be prepared</u>
- Initial cleaning is required to remove the inevitable build-up of biofilm inside the pipework. Biofilm is a mucous-like organic coating that lines the inside of pipes and fittings, and extracts nutrients and organic matter from the water
- Biofilm is a very supportive environment for bacteria and fungi, including pathogens. Microbes within the biofilm matrix are much more difficult to eliminate using chemical sanitisers than the same types of microbes in the water. The target is to remove excess biofilm from water systems
- 'Shock dosing' of water systems with higher concentrations of cleaning chemicals may be required for pipework delivering low-quality water. This should only be carried out when no pigs are present
- Clean water delivery systems open up the potential to supply nutritional and medicinal additives to specific groups of pigs, using simple technology that has been employed by the poultry industry for decades
- Delivery of additives effectively requires basic knowledge and understanding of water flow rates, water intakes, preparation of solutions, and volumes of water in the system
- It is suggested that all farms should know the daily water requirements of specific buildings and groups of animals, including water for cleaning

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# 1 Introduction

This document sets out to review the current state of provision of water to farmed pigs in the UK, and highlight areas where that provision may be limiting production or affecting health and welfare, thereby reducing the efficiency of the pig industry as a whole. Good water supply at pig level is a primary requirement for health and financially rewarding production.

Additionally, water can be used as a delivery method for medicines, vaccines and other treatments as an alternative to other routes of administration such as in-feed medication or injection. This report examines some of the possibilities that exist to better focus such treatments, and how to avoid possible problems in their use.

The potential of the growing pig to convert feed into high-quality meat is improving in line with genetic progress. Some farms achieve better growth and food conversion efficiency year on year, while others still have room for improvement, leaving a potential production gap across the industry. The provision of drinking water that is consistent in quantity and quality will help address some of these issues, and this document aims to assist more producers to achieve best practice in both water supply, and in the administration of water-soluble treatments.

This report is based on international standards and producer advice available from Europe, North America and Australia, coupled with practical experience and knowledge from UK pig production.

The chapters in this report are designed to be used either as a whole to evaluate the full provision of water and use of this through any production system, or as stand-alone sections to allow more targeted action to be taken on farm.

## 1.1 Background to water supply in the UK pig industry

All pigs, whether breeding, lactating, growing or finishing need a good supply of water to perform to their biological potential.

Nearly all pig farmers believe they supply their pigs' needs for water, yet closer examination of water systems on many farms shows that while supplies may be adequate for pig welfare, they may not be optimal in all cases and at all times to achieve maximum production efficiency.

Unlike in other pig production countries, few UK farms are standardised in the way they are constructed, or the way their pigs are managed. Around 40 per cent of the UK sow breeding herd is managed outdoors with many sites moving every few years necessitating transitory, surface-mounted water systems that are prone to freezing in winter and cause practical issues with supplying clean water to all stock at all times. A higher proportion of breeding sows are housed, as are the majority of post-weaned and finishing pigs, in indoor units where housing can be decades old with pipework and water supply systems of a similar age. Some units have grown in size over many years, meaning new buildings have been connected onto pre-existing and aged pipework, while even the infrastructure of new buildings has seldom been optimised to allow ready provision of water of a high enough quality to allow for in-water medication.

Such complexities and disparities between units and systems means a prescribed approach in terms of one single system blueprint applicable to all is not possible. Each producer or unit manager must consider their singular circumstances, with the aim of providing sufficient quality water to each and every pig on their units. This report describes the principles and practices of what “good supply” means.

**Opportunities for the refinement of antimicrobial use**

By April 2017, the World Health Organisation expects every country in the world to have a One Health Action Plan as required through the United Nations General Assembly resolution 70/183, aiming to tackle the global problem of antimicrobial resistance. In October 2016, the UK government committed to a reduction in antimicrobial use in agriculture in the UK, identifying a target of reducing from the present food animal use of 62mg/kg PCU (population correction unit) of antimicrobial to a level of 50mg/kg PCU by 2018. The pig industry is believed as of early 2017, to utilise almost half of all agricultural antibiotics in the UK, and the wider industry expects the pig sector to contribute to a reduction in use.

As the majority of use of antimicrobials in UK pigs is administered orally via in-feed incorporation, there are opportunities for reduction in overall use through a number of avenues, including changing the way antimicrobials are delivered. Medication through water systems can provide refinement in the delivery of antibiotics, such as faster implementation of treatment, more focused treatment of specific groups, and greater flexibility in terms of dose variation.

## 1.2 Guidance and statutory requirements

EU welfare regulations state that “all pigs over two weeks of age must have permanent access to a sufficient quantity of fresh water”.

The UK Code of Recommendations for the Welfare of Livestock (Pigs), 2012 (known throughout the industry as the Welfare Code) references legislation which requires that “watering equipment should be designed, constructed, placed and maintained so that contamination… of water and the harmful effects of contamination between animals are minimised”. It also contains recommendations on the quantity of water required by various types of pig and the associated flow rates required. These are shown in Table 1 below.

**Table 1. Daily water requirements and minimum flow rates**

| Weight of pigs (kg) | Minimum daily requirement (l/head) | Minimum flow through nipple drinker (l/min) |
|---|---|---|
| **Newly weaned** | 1.0–1.5 | 0.3 |
| **Up to 20kg** | 1.5–2.0 | 0.5–1.0 |
| **20 – 40kg** | 2.0–5.0 | 1.0–1.5 |
| **Finishing pigs up to 100kg** | 5.0–6.0 | 1.0–1.5 |
| **Sows and gilts pre-service and in-pig** | 5.0–8.0 | 2.0 |
| **Sows and gilts in lactation** | 15–30 | 2.0 |
| **Boars** | 5.0–8.0 | 2.0 |

*Source: Paragraph 72 of Code of Recommendations for the Welfare of Pigs*

Ninety-five percent of UK pig production is assured as complying with the Red Tractor farm assurance standards which gives requirements for adequate numbers of drinkers (Table 2a) or water trough lengths (Table 2b) for any given number of livestock, to ensure each pig has the ability to access a drinking point without undue competition from others in the group.

**Table 2a. Proposed Red Tractor Standards 2017**

**Drinkers**

| | **Nipples or Mini Bowls** | **Bowls** |
|---|---|---|
| **Ad-lib feeding** | 1 per 15 pigs | 1 per 30 pigs |
| **Restricted dry feeding** | 1 per 10 pigs | 1 per 20 pigs |
| **Wet feed (proposed for 2017)** | 1 per 30 pigs | 1 per 30 pigs |
| **NB Bowl implies access by >1 pig at any time** | | |

**Table 2b. Proposed Red Tractor Standards 2017**

| Troughs | Trough length |
|---|---|
| Pigs <15kg | 0.8cm of trough drinking space/pig |
| Pigs 15-35kg | 1cm of trough drinking space/pig |
| Pigs >35kgs | 1.2cm of trough drinking space/pig |

*Source: Red Tractor website-*
https://consultation.redtractor.org.uk/rta/pigs/supporting_documents/0.%20Pigs%20STD.pdf

RSPCA Freedom Food assurance standards (ed. November 2016) offer more definition of a drinking space and require additional provision equivalent to one drinking space per 10 pigs:

"One drinking place must be provided per 10 pigs. A drinking place is defined as the space required by a single pig whilst drinking. Drinking places should be spaced sufficiently to allow all places to be occupied at once without interference from pigs at the other drinking places. As a guide, a mini bowl and La Buvette-type drinker are both considered to be equivalent to a nipple drinker i.e. one drinking place. Other, larger bowls provide a surface of water that has the potential to be used by more than one pig at a time. Therefore, they are considered to be equivalent to two drinker places.

Where water is provided in troughs, the following space allowances must be provided:

- Pigs <25kg in weight should have a maximum of 100 pigs per linear m of trough
- Pigs 25 to 40kg in weight should have a maximum of 84 pigs per linear m of trough
- Pigs over 40kg in weight should have a maximum of 67 pigs per linear m of trough
- Troughs should be designed, constructed and maintained to ensure an even distribution of clean water within the trough. The water should fill the full length of the trough that is used in the calculation of the required trough length for the number of pigs present
- Pigs should be able to access the trough from all sides"

The Food Standards Agency (FSA) issued guidance in February 2016 for enforcement authorities, including local Trading Standards Officers and Environmental Health Officers, regarding the use of Private Water Supplies in Primary Food Production concerning EEC Regulation (EC) No 852/2004. This requires that “food business operations including the production, rearing or growing of food producing animals …are to take adequate measures to use potable, or clean water, whenever necessary to prevent contamination”.

This EC Regulation makes a distinction between “potable water”, which is defined as meeting guidelines on water quality intended for human consumption, and “clean water”, defined as “water that does not contain micro-organisms, or harmful substances in quantities capable of directly or indirectly affecting the health quality of food”. Agricultural premises are therefore expected to provide at least “clean water” to their stock.

The FSA Guidance notes on this reference the Defra Code of Practice for the Prevention and Control of Salmonella on Pig Farms (2000), which, regarding water, states:

> “The water supply should be from a mains or other chlorinated source. Water from a borehole is acceptable, provided tests for bacteriological quality give satisfactory results (Appendix 2). There should be an enclosed delivery system for water into livestock buildings which protects it from contamination. Water tanks, pipes and drinkers should be cleaned, flushed and disinfected as part of a regular routine. Open water troughs should be completely emptied, cleaned (including behind ball valve compartment flaps) and disinfected before restocking pens or outdoor pig unit paddocks.”

> Considerations on how to achieve these standards can be found throughout this report in later chapters.

## 2 Where do pig units get their water from?

### 2.1 Mains supply

Some pig production units are supplied by a public water supply with the mains water supplier having a duty to deliver 'wholesome water', with certain minimum quality requirements in terms of chemical content and microbiological levels. Accepting this public supply places a legal responsibility on the customer to ensure that mains water is not "contaminated, wasted, misused or unduly consumed" subject to various legal powers including the Water Industry Act 1991 and subsequent Water Supply Regulations.

All pig production sites pose the highest recognised risk of a serious health hazard in terms of contamination of any public supply – termed a Fluid Category Level 5 – because of the exposure of water to pathogenic substances and faecal material, as recognised under the various water regulations, which requires the creation of suitable vertical air gaps to prevent any possible backflow from contaminated areas into mains supplies.

Mains water is normally consistent in quality but not necessarily in quantity, in terms of flow rate or pressure. Quantity issues may be quite common as pig units are frequently at the end of mains lines. Mains pressure on entry to a farm can vary from 10 bar to 1 bar. Any sizeable pig facility represents at least a village in terms of human equivalent water requirement, and only a large diameter main in excess of two inches (50mm) diameter would be able to supply its peak demand.

Buffering of supply is achieved by on-farm storage either through a large communal storage tank, or individual paddock, building or room 'header' tanks or often a combination of the two.

### 2.2 Borehole supply

Increasingly, as a means of controlling production costs, water supplied to pigs in the UK is from ground-source or 'borehole' water, which, by nature, is derived from underground aquifers, with the borehole typically located on or very near to the pig production unit. The quality of water derived from these underground sources varies widely (NRM, 2016), representing the composition of the original rock of the geographical area, and the depth to which the borehole was drilled, which influences the amount of potential filtering by intervening rock that could have occurred. To reduce capital cost, many boreholes are only drilled to the minimum depth necessary to achieve a sufficient supply volume (personal communications: N. Woolfenden, 2016), and, while some treatment of the ground water may be performed, it is not necessarily treated to a level that would ensure it could be safely consumed by people – the so-called "human potable" standard. Providing such supply is purely for private use and with no connection to the public supply for back-up purposes; only the Private Water Supply Regulations apply.

Figure 1. (left) and Figure 2. (right) Borehole and reception tanks

In contrast to mains supply, borehole water can vary considerably in quality depending on the area of the country where the water originates – and although the mineral content of each deep borehole can remain relatively stable, its microbiological load at source can vary depending on recent rainfall and manure applications/run-off. This variation is minimised by well-designed and constructed lined installations. Owing to this potential degree of variation, it is recommended that a specific borehole contractor is consulted before installation, and to ensure a properly written maintenance schedule is in place. It is recommended that routine testing is carried out to confirm that the water source continues to be suitable for drinking by the pigs.

Borehole contractors should be asked to supply a written maintenance schedule. Clear guidance material is freely available, such as the following recommended documents:

http://www.groundwateruk.org/downloads/SEPA_borehole_construction.pdf
http://dwi.defra.gov.uk/research/completed-research/reports/DWI70_2_137_manual_old.pdf

A recent review carried out by RAFT Solutions Ltd, of data from 140 water quality samples (NRM, 2016) submitted from boreholes intended for use by livestock demonstrated that circa. 80 per cent of samples tested showed no risk to pig health or production from the commonly tested mineral contaminants (see Appendix 1 for acceptable levels used). There was however considerable variation in quality, with some proposed borehole sources being completely suitable for optimum pig health without significant further processing, yet 16 per cent indicated that sulphate, as $SO_4$, was above the 250ppm risk level, and 8 per cent with total iron above the risk threshold of 0.3ppm.

## 2.3 On-farm storage and passage through the unit

Various pipe types and systems of on-farm storage exist. The pipework infrastructure on many indoor units is often not obvious, being buried for protection and having frequently been extended in ad-hoc ways over many years, meaning the flow of water is not always logical, nor are the diameter and composition of pipes themselves consistent. While modern materials such as MDPE (medium density polyethylene 'plastic' or 'alkathene'), stainless steel or polyvinyl chloride (PVC) pipe may be used in new and refitted buildings, the basic framework of many supply systems within the unit may consist of aged and corroded cast iron or steel pipe runs.

On-farm storage is needed to cope with the peaks of demand throughout the day. This may be in the form of a pressurised and closed tank system, or a gravity-fed system. Raised header tanks are often used to feed in turn a low-pressure final supply system. This should preferentially be covered, to reduce the potential environmental contamination, but uncovered raised header tanks are also available.


Figure 3. Example of changes in pipe diameter as pipework runs through a building

The final presentation of water to the pig occurs via a valve-drinker or self-fill trough with myriad designs of each. By definition, each drinking point is in close contact with each pig's mouth and the mixed bacteria present within them, while depending on the type and position, some are susceptible to further fouling with urine or faeces.


Figure 4. (left) and Figure 5. (right) Example of valve drinkers

## 2.4 Guidance for the assessment of water quality by a producer

To assess quality of water, a producer should consider both:

- The primary source of water, eg sampling water quality at first entry point to the unit if mains-supplied, or at exit from the primary main storage or settlement tank if borehole-supplied
- The water as drunk by a susceptible pig after it has flowed and been stored through the various unit-specific water infrastructure sections, which may require a building-by-building assessment

The primary source should be checked for both mineral and bacterial load. Providing these areas are satisfactory at entry to the unit, it is generally considered unnecessary to check the water as drunk by the pigs for anything other than microbiological load, unless the plumbing within sections of the unit contains potentially polluting areas (eg lead piping).

It is not safe however to assume that water which is microbiologically acceptable at the primary source remains uncontaminated after passing through the rest of the system. On-farm storage, pipework and drinkers **without** regular sanitisation are frequently contaminated by microorganisms contained in biofilm, and may include potential pathogens (see boxes below and Section 4.5 for more information). A recent survey carried out by RAFT Solutions assessed the level of microbiological contamination on 50 units at various locations (Bishopton Veterinary Group clinical archive, 2016, unpublished). This found that the majority of these samples were acceptable for Total Viable Count (TVC) levels and total coliforms, but were unacceptable for levels of *E.coli* – see Appendix 2 for acceptable microbiological levels. If water is found to have an unacceptable level of microbiological contamination, refer to guidance in Section 6.1 for practical aspects of deep cleaning of water systems.

**How often should I test my borehole for quality?**

As a general indication of quality, check for abnormal smell and taint each week.

At first drill, a borehole should be checked for a full screen of dissolved minerals and microbiology. This would normally be repeated annually by the maintainer of the borehole installation.

If a borehole drains from sand/gravel, is less than 20m deep or able to be contaminated by surface water, then it is recommended to sample **twice per year as a minimum** – preferably once at low rainfall and once after heavy rainfall. A lesser screen for the main variable minerals plus a microbiological assessment is recommended (see Appendix 1 and Appendix 2 for acceptable levels).

### What should I test my borehole for?

An initial test for suitability should include any dissolved minerals potentially capable of damaging pig health and also microbiology. A suggested analysis would include:

- pH, hardness, Total Dissolved Solids (TDS), nitrate/nitrite and iron and manganese levels – see Appendix 1 for suggested dissolved mineral levels
- Microbiological check should also occur but requires a special microbiological sampling bottle and must be taken cleanly – See Appendix 2 for suggested microbiological standards and Appendix 3 for how to take a sample suitable for microbiological analysis


Figure 6. Example of a pre-sterilised water sample bottle suitable for microbiological analysis

## 2.5 Moving water through the farm to ensure an effective supply

In order to correct deficiencies in the quality of primary supply, particularly from private boreholes, treatment before any storage may be necessary to bring water up to a suitable standard for pigs – see Section 4 for water quality guidelines.

Treatments may include:

- Settlement via tanks to remove sediments, iron and manganese and to oxygenate passively
- Filtration to remove suspended solids, other contaminants, iron and manganese
- Ion exchange to soften water
- Oxygenation (active) to oxidise dissolved metals such as iron, hydrogen sulphide, and volatile organic chemicals (VOCs)
- UV treatment to reduce bacterial contamination
- Chemical dosing, eg chlorination, peroxidation

Acidification is another known treatment method to maintain a clean water supply. However, it is not cost-effective to acidify the entire water system on the farm, due to uses of water other than drinking (eg washing) and because acidified water can be damaging to infrastructure and surfaces, such as concrete.

**Boreholes** should be protected from contamination, and manures or slurries should not be stored or applied within 50m of a borehole (Defra, 2009) , nor should a borehole be located within 50m of a soakaway attached to a septic tank, sprayer wash-down pad, blind ditch soakaway or earth bank lagoon. In some limestone or sandstone areas, it may be necessary to further protect the borehole against microbial contamination from leaching or, more likely, percolation of contaminants through the surrounding strata or down the outside of any well casing installed, especially if it is unsealed at the bottom. The well driller will be able to advise based on geological knowledge and circumstances around the location.

**Primary storage or settlement tanks** should be made of polyethylene, stainless steel or, if steel, they should be galvanised, enamelled or lined with plastic. The inlet should be fitted with a control such as a ball valve to prevent overflow, and an overflow system installed to ensure at least 200mm freeboard between the inlet and maximum stored water level.

Water tanks should be protected against any environmental contamination, access by vermin or insects and from freezing. Contamination over time through debris in the environment (eg dust) and potential biological contamination from sources such as vermin can cause these tanks to become a source of high microbiological counts. Air gaps in structures should be protected by mesh screens of <6mm for rodents and 2mm for insects (Water Regulations Advisory Scheme Technical Support Group, 2012) and tanks should be easily accessible for cleaning. Sampling of water after the primary storage may be necessary and a secondary treatment may be justified.

The primary storage for the farm or unit should provide a buffer supply for use in the event of interruptions in water supply, eg from power outage or mechanical breakdown. There are no formal recommendations for the scale of any emergency supply but average daily intake can be estimated from Table 3. It is also important to take into account other uses of water such as pressure washing, liquid feed manufacturing or other activities on the farm (eg filling bowsers)

**It is a recommendation that all pig units should know the average daily water requirement of the whole unit, including pig water intake, pressure washing and all non-pig demands required from the same water source.**

**Table 3. Daily water requirements and minimum flow rates**

| Weight of pigs (kg) | Minimum daily requirement (l/head) | Minimum flow through nipple drinker (l/min) |
|---|---|---|
| **Newly weaned** | 1.0–1.5 | 0.3 |
| **Up to 20kg** | 1.5–2.0 | 0.5–1.0 |
| **20 – 40 kg** | 2.0–5.0 | 1.0–1.5 |
| **Finishing pigs up to 100kg** | 5.0–6.0 | 1.0–1.5 |
| **Sows and gilts pre-service and in-pig** | 5.0–8.0 | 2.0 |
| **Sows and gilts in lactation** | 15–30 | 2.0 |
| **Boars** | 5.0–8.0 | 2.0 |

*Source: Paragraph 72 of Code of Recommendations for the Welfare of Pigs*

In the **event of a failure in mains supply**, the water provider must immediately be informed of the presence of livestock, the welfare implications of failure to supply water and the scale of demand on an hourly and daily basis. It is recommended that all farms should have a current daily water requirement listing and that water suppliers are notified as a matter of routine so that any problems with supply can be dealt with promptly. Similarly, units should consider how emergency water supplies via tanker/bowser can be plugged into the existing farm water supply system to ensure that the water supply needs of the unit can continue to be met in time of failure of mains supply.

To distribute water around extensive sites, **pumping systems** may be required. Pumped systems should be closed and fitted with pressure vessels to reduce frequent pump stop/start cycling and they can also help detect possible losses through leaks. Secondary pumped circuits should be metred, and fitted with pressure regulators to prevent over-pressurisation.

Pumps should be standardised as far as possible to ease routine servicing and replacement. Pump systems require fitting with breakdown alarms to ensure a rapid response to any failures.

**Pipeline systems** can vary depending on the internal surface of the pipe. Pressure loss occurs along any pipeline owing to friction resulting from viscosity near the internal surface of any pipe. This is made worse by rough surfaces caused by corrosion, lime scale or biofilm build-up.

**Internal secondary storage tanks or header tanks** are common in many pig buildings in the UK, and provide some reserve within buildings to help balance supply and demand. As with primary storage tanks, they can provide an open face of water that can be readily contaminated by pig dust – which contains contaminants such as skin and faecal bacteria – as well as by vermin and insects. As they sit within areas occupied by pigs, the water within them can often rise to an ambient temperature, eg $20^{\circ}$C, which readily allows bacterial multiplication. This acts as a source of contamination to seed biofilm within the tanks and the pipelines they supply. For this reason, they should be correctly covered, as shown in Figures 7 and 8.

Header tanks provide a useful route of access to water for inspection or addition of additives in the piped areas they supply. They should be installed with isolation valves and easy-fit couplings to allow for simple removal and regular cleaning.

**NB** When placing header tanks within a building, consider the ventilation requirements and ensure that their location does not negatively change air flow patterns. Pigs behaving differently in pens close to tanks can be an indicator of this effect.


Figure 7. (left) and Figure 8. (right) Example of header tanks commonly used as a secondary storage facility on farm

Individual **valve drinkers** of either the nipple or bite type require a minimum supplied water pressure to deliver the required flow, typically between 0.2 and 4 bars (1 bar of pressure is equivalent to 10m head of water), see Table 4 for examples of flow rates at different orifice diameters – although these are correct for one manufacturer, it is recommended that the manufacturer's instructions are consulted.

Depending on design, valve drinkers may have an individual filter fitted before the valve to further prevent any gross contamination being delivered to the pigs. The orifice of the drinker refers to the opening through which water can be delivered and can subsequently affect the pressure or flow. Many valve drinkers are fitted with a pressure/flow regulator to allow the orifice diameter to be altered to correct pressure/flow – see Figure 9 for an example. Some drinker designs have a choice of inserts that modify flow rates, with different colours indicating different diameters of orifice. The manufacturer's instructions should be consulted to ensure their recommended flow, because supply water pressure will vary at times.


Figure 9. Demonstration of flow rate modifiers found in valve drinkers


Figure 10. Example of bite drinker components

Table 4 shows how the flow rates displayed in Table 3 can be achieved using different pressure and orifice combinations. The colour coding demonstrates inadequate, adequate or excessive flow across **all** stages of production. However, please note that flow rates are specific to each stage – see Table 3.

**Table 4. Example of flow rates (l/m) of a valve drinker with various internal orifice diameters***

| **Orifice (mm)** | **Pressure (bar)** | | | | |
|---|---|---|---|---|---|
| | **0.2** | **1** | **2** | **3** | **4** |
| **0.8** | 0.15 | 0.34 | 0.48 | 0.65 | 0.88 |
| **1.0** | 0.35 | 0.80 | 1.20 | 1.72 | 2.30 |
| **2.0** | 1.31 | 2.10 | 2.80 | 3.70 | 4.30 |

*Source: AHDB Pork, 2016*

*It is recommended that the manufacturer's instructions for the specific product used are consulted.

Key: Red = inadequate flow; green = adequate flow; amber = excessive flow

**Example:**
Growing and finishing pigs require a flow rate in the range of 1.0 and 1.5l/min – as shown in Table 3. Table 4 shows how this can be achieved with:

- An orifice of 1.0mm at 2 bar pressure which should deliver a flow of 1.20l/min

or

- An orifice of 2.0mm at 0.2 bar pressure which should deliver a flow of 1.31l/min

**Troughs and bowls** provide a small internal buffer supply of water, meaning the flow rate at their inlet valve can be half that of an equivalent group of nipple drinkers.

**Any drinker in contact with the mouth of a pig will be exposed to bacteria and other pathogens picked up or carried by that pig. Drinkers clearly act as a mechanism for transfer of infection within a group. Drinkers and water systems must be competently sanitised between batches of pigs to achieve true all-in/all-out hygiene standards.**

The **risk of contamination** is greatest with bowls and trough drinkers as they provide an open face of water that can become soiled with faeces and are more difficult to clean regularly. But they do provide easy access, a reserve supply and waste less water if properly positioned. The risk of contamination can be reduced where possible by careful siting of drinkers. Individual nipple drinkers probably supply water with the least chance of contamination if served by a clean supply to that point, but can waste more water if poorly set up. See Section 5 for more information on choosing the correct drinker.

**What are the risks of improper distribution of water through any unit?**

Many pig units in the UK have changed over time with buildings demolished and new ones built to extend the existing unit. Frequently the water infrastructure has not been reviewed in line with unit expansion, leaving the furthest reaches of a unit with reduced supply. This is probable especially during peak demand in summer and when simultaneous demands, eg for washing, are considered. This can result in header tanks holding insufficient water for the needs of the pigs they supply, resulting in transient shortages or pressure changes that mean flow rate to drinkers are insufficient, and pig water intakes fall, reducing feed intakes and increasing vice or health risks.

Aged pipes can have built-up internal  limescale, iron/manganese deposits or biofilm sufficient to reduce flow significantly.

Some pipe alterations may have produced dead-end spurs on water systems that can be a potent source of microbiological contamination. Any stagnant water in pipework increases the risk of bacterial growth.

For further information and an example calculation, see Appendix 4. However, when designing a new water supply system, it is advised that you consult a competent livestock plumber who should be able to follow the above considerations and carry out the relevant calculations for you.

## 2.6 The importance of flow rate at individual drinkers

Each size of pig has a preferred rate for water to be supplied to it that will allow efficient swallowing with no wastage, yet not limit intake overall. Suggested flow rates from individual drinkers are shown in Table 5 below:

Table 5. Recommended flow rates per stage of production

| Stage of production | Recommended flow rates (l/min) |
|---|---|
| Farrowing | 1.5–2.0 |
| Weaner | 0.7 |
| Grower 1 | 1.0 |
| Grower 2 | 1.5 |
| Finisher | 1.5–2.0 |
| Dry Sows | 1.5–2.0 |

*Source: Paragraph 72 of Code of Recommendations for the Welfare of Pigs*

Flow rates **slower** than the recommended mean compromise either water intake or feed intake since a pig will only partly compensate by spending longer at a drinker, or by extending the duration of its feeding/drinking activity over the daytime period.

Alternatively, **higher** flow rates lead to pigs spilling water at the drinker, resulting in wastage, wetting of pens (which may make them cold), and excessive slurry production.

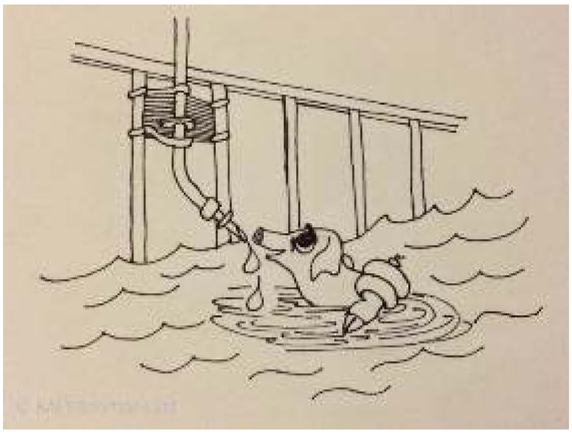

Figure 11. Excessive drinker flow rates increases water wastage and does little to increase water intake
*Source: adaptation from Prairie Swine Centre*

Pigs eat preferentially at certain times of the day. This is known as the 'diurnal pattern' of feeding. The subsequent drinking behaviour of grower/finisher pigs means that multiple drinkers will be in use in each pig house at times of peak drinking. If the delivery pipework is not correctly designed, the result of multiple drinkers being used simultaneously is that flow rate will fall along the line; in worst cases, some drinkers may not get any water. Thus pipes and pressure should be specified in accordance to demand, and if possible a reserve should be designed into the delivery system as a whole.

The variation in drinking behaviour of newly weaned pigs can also alter the water flow through the system until their drinking behaviours settle. Weaned piglets will attempt to drink together as a normal behaviour learnt when suckling, and any restriction on water intake immediately post-weaning will, at best, restrict feed intake and therefore growth rates or, at worst, result in a proportion of 'fading' weaners.

Studies in the UK pig sector (Robertson and Malloy, 2003; Robertson, 2006) show that an average of 15 per cent of individual drinkers gave lower than optimal flows, suggesting that significant productivity gains could be achieved by checking and improving flow rates.

### What can cause low flow rates?

Causes of low flow can include:

- Inadequate initial primary source
- Insufficient volume reserve in the building at peak demand (NB: Always take into consideration additional water demands, eg pressure washing at peak drinking times)
- Inadequate pipe sizes and layout
- Inadequate on-farm storage capacity (whole farm or internal building)
- Inappropriate siting of header tanks within internal buildings
- Incorrect drinker choice
- Incorrect drinker set-up
- Drinker malfunction, eg from corrosion
- Restriction of flow in pipes caused by scale or biofilm build-up
- Blockage of filters

### When should I check my flow rates?

All drinkers should be checked for function each day as part of routine stockperson tasks, with a specific flow rate measurement on each fill of a pen or building.

To ensure flow rates are optimal throughout the unit at all times, flow rate measurement should be taken during peak demand such as in summer and in the middle of the afternoon for grower/finisher pigs, or immediately after the feeding of restricted fed sows such as lactating animals.

### Where should I check my flow rates?

Flow rates should always be checked at the first drinker in any particular line, to indicate issues with the initial supply **and** at the last drinker in the line, while 10 per cent of drinkers in that line are open or in use to indicate adequate reserve.

### How do I check my flow rates?

For more information on how to check flow rates at each drinking point, please see Appendix 5.

### What can I do to address incorrect flow?

A water infrastructure plan of the whole site would be a good place to start, with a review of the present plumbing arrangements and pig needs. Consideration should be given to the causes of incorrect flow, such as:

- Initial primary supply, ie the whole farm's mains size or borehole capacity – do not assume the original supply is still sufficient; consider increases in growth rates, prolificacy and finishing weights
- Any requirements for pressure washing especially if coincident with peak pig demands, allowing for the diurnal water intake pattern
- Adequate spare capacity for expansion of the unit
- Suitable size pipework to each building to supply and maintain flow
- On-farm storage capacity, whether for whole farm via large storage vessel or internal building header tanks of correct size
- Pipes restricted with sediment or biofilm build-up (cleaning or replacement would then be required)
- Header tanks needing re-siting in the middle of pipe runs to achieve adequate flow to the most distant drinking points
- Pressurised systems
- Type of drinker selected for the stage of production of pigs, as well as drinker location within the pen (drinkers can degrade over time, leading to malfunction)
- Presence of debris within the water system – this can lead to the blockage of filters within the system, restricting flow. In which case (cleaning or replacement would then be required)

**Why should I measure my total water usage?**

Comparing typical pig water usage within your own farm usage can be helpful in identifying possible outliers with regards to water usage and highlight potential water supply issues. The examples below use farm data to demonstrate the difference between recorded and theoretical use.

Water usage on finisher-only sites across the UK (n=20) typically averaged 6l/pig/day over one year, with a typical range of 4–8l/day (Douglas, 2016). However, one farm recorded a water usage of 12l/pig/day and the highest one was 15l/pig/day. Across a 1000-head finisher site, this would lead to $9m^3$ of extra water usage (9 tonnes per day). The increased volume may represent waste from leaks or poorly sited and functioning drinkers. This can lead to additional slurry storage and handling cost if the extra water used enters the slurry system.

Less than average water usage levels can be similarly detrimental. For example, average daily usage for nursery sites in the first four weeks post-weaning averages around 3l/pig/day. However, a recent study recorded the lowest usage at an average of only 0.68l/pig/day on one site (Douglas, 2016). Because of the marked connection between feed and water intake, this low level must reflect subsequent poor post-weaning feed intake and a considerable loss of growth opportunity.

Changes in the pattern of water usage can be recognised by ongoing measurement via flow meters linked to remote monitoring – see Appendix 6 for example summary data (Douglas, 2016). Such changes show considerable potential as early indicators of both health and welfare problems in groups of pigs, particularly in terms of vice issues.

**What are the problems with an inadequate quantity of water supply?**

Sudden, complete failure of water intake by a pig results in a serious disease issue expressed as initial depression, leading to nervous signs of incoordination, head pressing, falling backwards, recumbency and rapid death in individual pigs – known as 'salt poisoning' (White, 2006; White 2005). Hence broken pipes, freezing or physical blockages will quickly cause a very severe welfare and economic issue. A veterinary surgeon should be consulted if any pig shows nervous signs, to ensure both a correct diagnosis and most effective rehydration. Prevention obviously depends on an adequate and well-maintained water system.

If drinking points such as nipples are insufficiently available, increased competition for drinkers will occur, which results in interrupted visits to the drinker, lower intake of water by less dominant animals in any group and greater spillage. Restricted access to water results in reduced feed intake by these lower-order animals, which contributes to uneven growth within groups (White, 2006). A more compromised access to water or inconsistent flow will further contribute to vice.

Longer-term inadequate or inconsistent water supply or flows can result in:

- Increased aggression or stress levels within groups, which can result in vices such as vulval biting in sows or tail biting in weaned pigs
- Urinary tract infections, which may manifest as vulval discharges in breeding animals
- Lowered growth rates and food conversion efficiency
- Uneven growth within groups
- Gastric ulceration
- Increased levels of torsion of the stomach and intestines including 'whey bloat'
- Lowered weaning weights

# 3 What are a pig's need for water in terms of quantity?

The requirements of a pig for water varies depending on a number of factors:

- Age
- State of production, eg lactating sow versus pregnant sow
- Consistency of feed, eg wet feed versus dry feed
- Quantity of feed
- Ambient temperature
- Drinking water temperature
- Group size

## 3.1 Sows

The water requirements of sows are driven by their patterns and quantities of feed intake, and their state of production.

**Pregnant sows**
Pregnant sows in temperature-neutral conditions (Table 6) and dry-fed require around 2.5–3 per cent of their body weight as daily water intake, with over 75 per cent of this intake occurring around the time of feeding. Pregnant sows are usually fed once per day such that a 250kg sow might require 7–8l of water per day, 5–6l of which is concentrated around the once-a-day feed. This inevitably creates a daily peak in water supply requirements, with the potential to create competition and lead to aggressive behaviour. On average, a sow will spend a maximum of 15 minutes drinking at any one time, although this falls to as low as five minutes in the first few days post-farrowing (Gonyou, 1994). Sows fed sequentially through an electronic sow feeder (ESF) system also mainly drink sequentially, which creates a less concerted demand for water access. Hence, access to water can be a point of competition and lead to aggressive behaviour in group-housed sows.

**Table 6. Ideal room temperature ranges for pigs at different stages of production**

| Stage of production | Room temperature (°C) |
|---|---|
| **Sows** | 15–20 |
| **Suckling pigs** | 25–30 |
| **Weaned pigs (3–4 weeks)** | 27–32 |
| **Weaned pigs (>5 weeks)** | 22–27 |
| **Porkers** | 15–21 |
| **Bacon pigs** | 15–18 |

*Source: Paragraph 55 of Code of Recommendations for the Welfare of Pigs*

**Lactating sows**

Lactation increases the physical demand for fluid by the sow and water consumption is proportional to litter size and feed intake. There is a relationship between sow appetite and water intake, with poor water supply during lactation limiting sow appetite and milk output, ultimately reflected in lowered total litter weaning weight. In peak lactation during high ambient temperatures, sow demand for water may rise to 40l/day although some of this may reflect wastage – see Table 1 in Section 1.2. Sows can use the water source for evaporative cooling or learn to run water over their mouths and snout for cooling purposes. Individual farrowing accommodation water demands will therefore vary depending on factors such as feeding practices and ambient temperatures. Sows given large quantities of feed twice daily create a high demand over a short period of time, which means that maintenance of suitable flow rates at each individual sow drinker is critical to achieve maximum lactation performance. Conversely, ad lib feeding or more frequent automated feeding of lactating sows smooths out room or building demands for water throughout the day, although 75 per cent of water intake still occurs between 08:00 and 20:00.

**Sows at the point of weaning**

Sows at the point of weaning are often provided with high levels of feed until the point of service, depending on their body condition, as this results in consistently better and stronger heat expression. Hence high water intake is also critical at this time, and to allow every weaned sow optimum access will require greater drinker provision than in the typical gestation housing.

Drinking points can be an area of competitive behaviour in groups of sows, so should be widely spread or protected and allow adequate intake in a short time; water troughs can provide this.

Think carefully about water provision if vulva biting occurs; check drinkers daily to ensure adequate flow. Sows can be slow to drink in the first few days post-farrowing, so supplementary water and stimulus to drink (eg getting sows up from lying position) may be required to establish a good lactation.

Consider the differences in drinker type between gestation and lactation accommodation – gilts especially may need training to use a new drinker type.

**Never, even unknowingly, limit the water intake of a lactating sow or production will suffer.**



Figure 12. (left) and Figure 13. (right) Examples of different drinker set-ups provided for sows

**Outdoor pigs**

Providing water to outdoor pigs can prove particularly challenging on extensive flat sites and during the winter months. Outdoor pigs housed in arks or similar shelters tend to drink less frequently than sows indoors but spend longer at each bout of drinking (Anderson and Pederson, 2014a). This means that deep open-face troughs or shallow metal wallows have been the favoured method of supplying water, since they provide a decent, localised storage capacity. However, troughs are prone to fouling by pigs themselves, other biological vectors such as birds, and flooding or poaching – see Figure 15, 16 and 17). Consequently, they are difficult to keep clean.

Therefore, drinking troughs themselves can be a source of pathogens such as *Salmonella* spp., *Brachyspira* spp., *E.coli* and other coliforms. It has however been demonstrated that outdoor troughs can be kept more hygienic by applying good cleaning protocols (Robertson, 2006).

Figure 14. Sows prefer clean water provided via a trough to dirty surface water

Figure 15. Examples of water provision for outdoor pigs highlighting the challenges faced through flooding and poaching

Figure 16. Open-face troughs are prone to fouling with mud and faeces so can be a source of many pathogens including *E.coli* and *Salmonella*


Figure 17.

## 3.2 Piglets

Suckling piglets have a low water requirement due to the volume of water consumed as a constituent of milk. Their direct water consumption is therefore typically less than 50ml/day for the first few days of life, unless sow milk production is compromised. It is recommended that piglets are initially provided with a free dish as their provision of a water source while they learn how to use nipple drinkers. This is important to ensure that their water requirements are met and to prevent any negative impacts on production (Fraser et al., 1993). Provision of nipple drinkers in the farrowing environment is recommended as a positive strategy to encourage suckling pigs to learn how to effectively drink from them and help reduce any performance dip seen post-weaning due to a lack of water consumption caused by unfamiliarity with the source.


Figure 18. Piglets given supplementary creep feed always need good water access

The provision of creep feed increases the water requirements of the suckling litter, which is best provided from an open-face bowl or dish initially for a suckling pig while they learn how to use a nipple/bite drinker (Fraser et al., 1993). However, it is still recommended that nipple/bite drinkers are provided in the farrowing environment to encourage piglets to learn how to use them before weaning.

With increasing litter size, the provision of sufficient water of suitable quality, especially in summer, is likely to become more relevant.

## 3.3 Weaner

Water provision around the time of weaning is highly critical to prevent dehydration, stimulate optimal appetite and ensure that growth is promoted right from the point of weaning. There is often a drop-off in water consumption per animal at this time, yet conversely water disappearance rates can be high since piglet exploratory behaviour around drinkers can result in excessive wastage (Douglas, 2016). Weaner piglets have an acute sense of smell so that off 'odours' and taints will put them off drinking, which in turn limits feed intake at a critical time of life. Group-feeding behaviour, habituated from the frequent suckles of litter behaviour, is retained for at least two weeks post-weaning, meaning many animals in the group eat, then drink together frequently. Feed space and drinker provision should not be allowed to become a limiting factor on total nutrient intake at this time. Even when piglet nipple drinkers are present in the farrowing pens, some piglets will not immediately use a nipple drinker, so an open face of clean water provided via a turkey drinker, open bowl or river trough will attract more weaners to drink more readily.

To encourage weaner pigs to drink more readily, consider the following:

- Water supply must be clean and untainted
- Open-water faces are preferable in the first two weeks after weaning
- Watering and feeding points should be close together to facilitate frequent return trips
- Ready fouling of open-water sources should be preventable
- Open-water sources will need emptying, cleaning and refilling twice per day

Peak water usage in a weaner deck is typically seen around day two post-weaning. This is indicative of exploratory behaviour of young pigs. Figure 19 shows an example of water usage in a weaner deck during the first two weeks post-weaning. The peak seen around day two represents wastage, not intake, and is highly relevant to consider if, for example, weaners are medicated or vaccinated through the water system during those first couple of days.

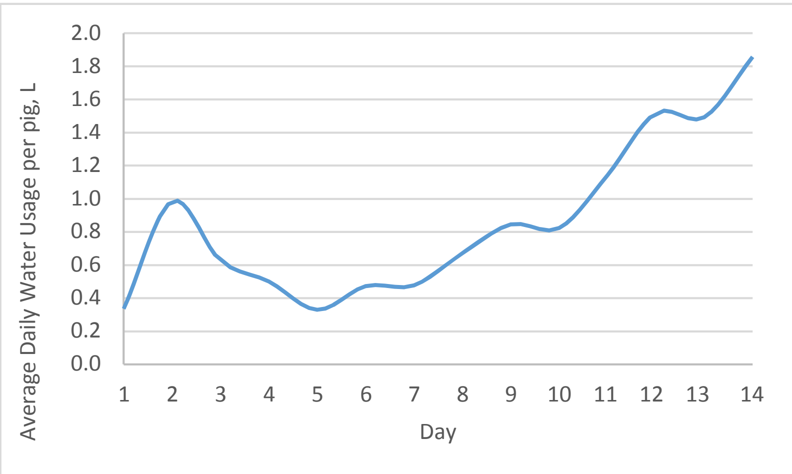


Figure 19. Typical average daily water usage per pig in the first 14 days post-weaning (Douglas, 2016)

Figure 20. (left) and Figure 21. (right) Weaner pigs provided with an additional open face of water sources via turkey drinkers as well as nipples for the period shortly after weaning to encourage drinking


Figure 22. Additional river trough included in a straw yard for the first few days post-weaning to encourage drinking. Monitoring cleanliness is vital as these are readily contaminated.

## 3.4 Grower and finisher pigs

Growing and finishing pigs show the most variable consumption, influenced by other environmental factors such as temperature and diet form. All growing pigs utilise around 8–10 per cent of their water intake for growth and high-appetite advanced genotypes with a high feed intake potential may find water supply a limiting factor for optimal growth. When dry-fed, a growing pig requires between 2.2–2.8l of water for every kilogram of feed intake, equivalent to approximately 70–100ml of water per kilogram of body weight.

**Typically, pigs from weaning to around 30kg require 10 per cent of their body weight as water, with a reducing requirement to around 7 per cent of body weight approaching slaughter weight.**

High water intakes are needed where diets are high in protein relative to the ability of the pig to lay down muscle, or high in salt (Brooks, 1994).

Growing pigs will spend a maximum of 30 minutes per day drinking water and 85 per cent of this consumption happens within 10 minutes of eating. Water intake patterns therefore closely follow food intake patterns, which are not uniform throughout any 24-hour period but are related to the daytime period, as most meals are taken during the natural daylight hours, with a peak of feed and water intake in mid-afternoon. This gives rise to a typical 'diurnal' intake curve as below in Figure 23.

Although this is a typical pattern, all systems will be slightly different, and therefore automatically monitoring water flows allows for any deviations from the norm to be seen and acted upon. Further examples are given in Appendix 6.

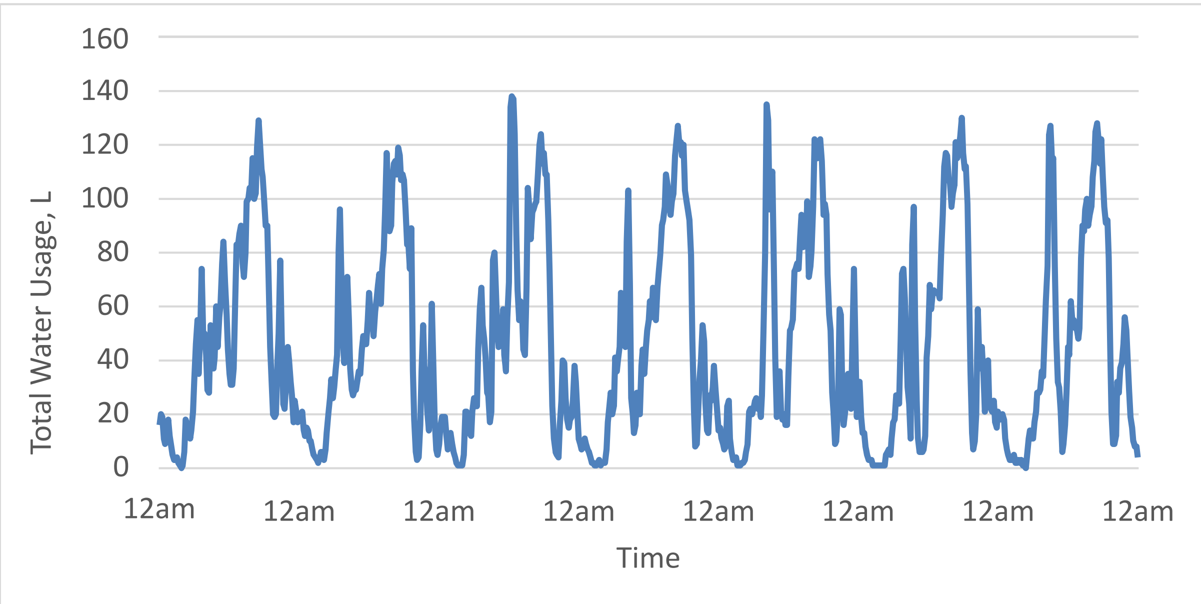


Figure 23. Diurnal drinking pattern behaviour displayed by ad lib pigs (Source: Douglas, 2016)

If room temperature exceeds the neutral temperature zone of any particular pig (Table 6), water use rises and may even double, though not all this amount is drunk by the pig, with some only used for cooling purposes.

Please note the following:

- Providing true ad lib intakes of water will promote feed intake and fast growth
- Pigs prefer colder water when ambient temperatures are high
- Water demand will be highest in mid-afternoon
- **Wet-fed pigs must have access to a separate water supply**. They must not be allowed to become thirsty, especially if fed at specific times of day through a communal trough, otherwise intestinal problems, such as bloat or torsion, can occur
- Water or wet-feed spillages onto solid floored pens can result in pig discomfort and lead to vice. Gaseous emissions will also increase

# 4 What does a good water supply look like in terms of quality?

Assessment of the quality of water can be split broadly into three categories:

- **Physical appearance**: odour, cloudiness or turbidity, gross contamination, eg sand or silt
- **Chemical and mineral contamination**: calcium, magnesium, sulphate, iron, manganese
- **Microbiological contamination**: bacterial, fungal or parasitic agents

## 4.1 Physical contamination

Physical contaminants are usually absent from mains water supply and should normally be removed by filtration of borehole supply. Any contamination visible to the naked eye or detectable by the nose indicates the need to assess the overall system to determine the source of the contamination. Turbidity is the cloudiness of a fluid caused by large numbers of individual particles that are generally invisible to the naked eye. Turbidity is important in that lack of transparency will render any UV treatments ineffective and is likely to affect the efficiency of any further water sanitisation. At the very least the presence of sediments will affect the correct function of drinkers, pumps and washers.

## 4.2 Chemical contamination

Chemical contamination should not be a practical issue with mains water supplied by a public provider, but each geographical area of the UK will yield ground water with different characteristics such as pH, hardness and mineral content. Different minerals have varying effects in terms of challenge either to the pig's health or to the unit infrastructure with regard to chemical or physical reactions. Borehole water should be analysed at least annually for a range of parameters dependent on the perceived risk, following an initial full screen of any newly commissioned borehole.

The **acidity/alkalinity (pH) level** of the primary source of water should be assessed and known irrespective of source since, while pigs are tolerant of widely variable pH levels, pH can have detrimental effects on products added to water. For example, chlorination gives a reduced water sanitisation effect at high water pH (alkaline water >pH7) and the solubility of many medicines added to water is pH-dependent.

An acceptable range of pH in primary water supply is pH5–8 in terms of pig health but acidification of drinking water to pH4 appears to give benefits to intestinal health in pigs – see Section 6.2.

**Total Dissolved Solids (TDS)** is a measure of all dissolved minerals in water. Table 7 indicates the impact of increased TDS levels in water for pigs. Assessment of TDS can be a useful first step when checking the risk of one or more minerals being present in excessive amounts and potentially having detrimental health or production effects. Variations in TDS levels can be used to focus further sampling to look at each individual mineral. However, a normal TDS level should not be taken to indicate that all minerals are present at acceptable levels and demonstration of clinical signs amongst pigs might suggest that analysis for individual minerals is appropriate. Table 8 shows the potential impact of increased concentrations of individual minerals in drinking water.

**Table 7. Evaluation of the water quality for pigs based on TDS**

| Total dissolved solid (mg/l) | Comments |
|---|---|
| **<1,000** | No risk to pigs |
| **1,000–2,999** | Satisfactory for pigs. Mild diarrhoea may occur in pigs not adapted to it |
| **3,000–4,999** | Satisfactory for pigs. May cause temporary refusal of water and temporary diarrhoea |
| **5,000–6,999** | Reasonably safe for pigs. Higher levels should be avoided for pregnant/lactating pigs |
| **7,000–10,000** | Unfit for pigs. Risky for pregnant, lactating or young pigs, or those exposed to heat stress/water loss |
| **>10,000** | Not recommended for use |
| NB The above ranges are indicative; the numbers are not absolute. Take advice from your veterinary surgeon for each specific situation and use | |

*Source: van Heugten, 2000*

Pigs often have higher tolerances to many minerals found in water than humans. For instance, pigs are very tolerant of high **sodium** and **chloride** levels, with only the bad taste created likely to reduce water intakes and therefore affect productivity indirectly – see Table 8.

High **sulphate** levels (>250ppm) (Table 8) in water can cause diarrhoea in pigs unaccustomed to such levels, since all the major sulphate salts are laxative. This has been shown to be a problem in mid-west America, especially when pigs are moved from an area of relatively low sulphate into an area of high sulphates (eg at weaning, with geographical changes). In a recent analysis of UK borehole water samples (NRM Laboratories, 2016), up to 16 per cent of those from 140 livestock units were above the recommended sulphate levels. High sulphates may therefore be a problem in the UK, hence regular testing would be recommended where looseness is present.

**Nitrates** can be converted to more toxic nitrites in the body of the pig, which can have detrimental effects on the ability of the blood to carry oxygen. Young pigs appear more resistant to the detrimental effects of nitrites than human babies (van Heugten, 2000). High levels of nitrates were found in around 7 per cent of potential borehole sites in the UK (NRM Laboratories, 2016) but were believed to be associated with agricultural contamination of boreholes, for example by nitrates originating in slurry or fertiliser application. High nitrate levels should always prompt a further test on the bacterial quality of the water.

**Calcium** is frequently found dissolved in ground water and while well tolerated by the pig, its presence can interfere with the absorption of phosphorus and the effectiveness of the tetracycline group of antibiotics, among others. Calcium also forms part of the 'hardness' rating of water along with magnesium. Hard water risks limescale build-up within pipelines and drinking systems, which can especially reduce flows, while calcification of biofilm protects microorganisms from the effects of water sanitisation such as chlorine.

Dissolved **iron** salts are common in ground water from certain areas of the UK and high levels are often found to be problematic in pig waterlines. Even at levels of 2–3ppm, iron can still have an indirect, detrimental effect on pig health as it can be utilised by bacteria, leading to the production of insoluble iron compounds that can block the waterline, limiting water delivery to the pigs (van Heugten, 2000, Patience, 2011. Iron is also a vital element utilised by *E.coli,* therefore fluctuations in dissolved iron levels are often adapted to by the bacteria, allowing its survival and promoting detrimental effects associated with coliform infection (personal communication P. Wigley).



Figure 24. (left) and Figure 25. (right) Evidence of iron contamination found around the exit of a pipe and from the inside of a pipe


Figure 26. Build-up of iron deposits found on a water filter

Dissolved **manganese** salts behave similarly to iron, becoming insoluble upon exposure to air, creating a black-coloured precipitate that is similarly able to block drinkers and pipelines. There are limited, directly toxic effects on pigs of high manganese levels.


Figure 27. Example of manganese precipitate coating the inside of a pipe



Figure 28. (left) and Figure 29. (right) Evidence of iron (orange) and manganese (black) deposits within limescale deposits left from a piggery sprinkler system

The levels of **magnesium** detected in water can vary across the country, depending on location and season. Currently, there are no recommended guidelines for acceptable levels of magnesium in the drinking water provided to pigs. An upper limit of **300–400ppm** has however been suggested for other livestock species.

**Table 8. Potential chemical components of water and risk levels**

| Mineral | No Risk (ppm) | Risk (ppm) | Detrimental effects for pigs |
|---|---|---|---|
| **pH** | 5–8 | >9 and <4 | No direct effects |
| **Ammonia** | <1 | >2 | Limited effects |
| **Nitrite (as N)** | <0.1 | >1 | May reduce oxygen binding capacities of haemoglobin |
| **Nitrate (as N)** | <25 | >100 | Rarely seen. May be concurrent with bacterial contamination |
| **Chloride** | <250 | >1,000 | Poor taste may reduce water intakes |
| **Salt (as NaCl)** | <1,000 | >2,000 | Acute salt poisoning |
| **Iron** | <0.2 | n/a | Blockage of waterlines may result in poor intakes. Scour at high levels |
| **Manganese** | <1 | >2 | Limited detrimental effects |
| **Sulphate** | <100 | >250 | Diarrhoea in young pigs at high levels. Limited effects and adaptation possible at lower levels |
| **Magnesium** | <400 | n/a | Limited detrimental effects |
| **Calcium** | Max. 1,000 | n/a | Limited detrimental effects |
| NB The above ranges are indicative; the numbers are not absolute. Take advice from your veterinary surgeon for each specific situation and use | | | |

*Source: Dutch Water Standards, van Heugten, 2000*

## 4.3 Microbiological contamination

Microbiological contamination of water within a pig unit is common and can occur at any point in the supply, from primary source to any individual drinking point. Contamination may be bacterial but can also include fungi, moulds, viruses and parasites. Routine assessment of microbiological contamination describes the levels of living bacteria present in any given sample, practically grouped into the Total Viable Count (TVC) of bacteria grown in nutrients held at 37$^{o}$C to select for those able to grow at mammalian body temperature, and the TVC of bacteria grown at 22$^{o}$C used as a proxy for bacteria able to survive at an ambient temperature. Detection of total coliform bacteria is associated with faecal contamination of water. Further differentiation within the coliform species should target *E. coli spp.*, assumed to be pathogenic, ie capable of some deleterious health effects in pigs. In certain cases, it may also be prudent to look for the presence of *Clostridia* spp..

To assess whether water is microbiologically clean enough for human consumption, the Drinking Water Inspectorate uses the criteria shown in Table 9 below.

**Table 9. Acceptable levels of microbiological contaminants in water for human consumption**

| Microbiological Measure | Acceptable level |
|---|---|
| **TVC (at 22$^{o}$c)** | <100/ml |
| **TVC (at 37$^{o}$c)** | <3/ml |
| **Total coliforms** | None detected in 100ml |
| ***E. coli*** | None detected in 100ml |

*Source: Drinking Water Inspectorate, 2016*

There is a widely held fallacy within pig production that pigs have the ability to tolerate water with higher microbial levels than humans without developing any signs of poor health, but this is plainly dependent on the physiological and immune status of the pig, as well as the particular type of bacterial species present. Therefore, Red Tractor adopted the criteria shown in Table 10 below as part of its farm assurance programme, which takes effect from 1 October 2017.

**Table 10. Acceptable drinking water parameters for livestock**

| Microbiological Measure | Acceptable level |
|---|---|
| TVC (at 22$^{o}$c) | <1000/ml |
| Total coliforms | <100 in 100ml |

*Source: Red Tractor Farm Assurance Pigs Standard, 2017*

**Any Gram-negative bacteria such as coliforms contain complex carbohydrate molecules called lipopolysaccharides (LPS). LPS act as potent stimulants of the immune response and exposure to them is known to decrease appetite and reduce food conversion efficiency in pigs.**

Water systems carrying a high load of biofilm (see Section 4.5 for more information) are likely to harbour many bacteria, and so lead to the bacterial contamination of water delivered by the system, even if the original source of water is relatively uncontaminated. However, even systems with a low apparent biofilm can still result in high bacterial contamination in water as drunk by pigs.

The results from a comprehensive survey of water quality on UK quality-assured pig units (Robertson, 2006) found that the majority of samples were either considerably above or below the suggested TVC threshold of 1,000 viable bacteria per ml, and that only 1.8 per cent of all TVC results were between 1,000 and 2,000 TVCs per ml of sample. This suggests that the proposed cut-off level is appropriate to demonstrate significant problems with microbiological contamination within a water delivery system.

The **frequency** of testing is however the most important factor to allow producers to properly understand the microbiological levels present in their water delivery systems. Although accredited laboratories are available, it is recommended that the frequency of testing be upheld with a non-accredited laboratory if cost is the barrier to testing.

The environment of the water delivery mechanism in pig housings provides ideal conditions in terms of temperature and humidity to promote the survival of many common pig infections, with their survival time in water frequently exceeding the downtime of pens or buildings between successive fills or batches – see Table 11. As such, these areas can be a significant reservoir of pathogens and represent a major infection route of naïve pig groups introduced into seemingly clean environments.

**Table 11. Survival times of commonly implicated pathogens (and associated disease)**

| Pathogen | Expected survival time in water | Expected survival time in faeces |
|---|---|---|
| *Mycoplasma hyopneumoniae* ((Enzootic Pneumonia) | 31 days | 31 days |
| *E. coli* | Variable (few days-year) Will still grow in sterile water. Low temperatures/toxic metals (lead, copper, mercury and cadmium) induce a dormant state | Variable (few days-year) dependant on nutrient or energy availability |
| Porcine Reproductive and Respiratory Syndrome (PRRS) virus | 11 days | 7 days |
| *Brachyspira hyodystenteriae* (Swine Dysentery) | 61 days (at 5°C) | 61 days (at 5°C) |
| *Salmonella spp.* | 54 days | 3 months |
| *Streptococcus suis* | 1–2 weeks | 8–104 days (temperature-dependent <20–0°C, respectively) |
| *Actinobacillus pleuropneumoniae* (Pleuropneumonia - APP) | 3 weeks | Up to 3 weeks |
| Swine Influenza | >32 days | >6 weeks (at 5°C. Survival times reduced with increased temperature) |

*Sources: Villarreal, 2010; van Elsas et al., 2011; Drew and Patron, 2004; Alverez-Ordóñez et al. 2013; Constable et al., 2016; Gray and Fedorka-Cray, 2001; Moore et al., 2003; Clifton-Hadley and Enright, 1984; Loera-Muro and Guerrero-Barrera, 2013; Brown et al., 2009; Bøtner and Belsham, 2012*

**What are the potential consequences of high microbial levels in water?**

Bacterial challenge from water containing a microbial level above the recommended acceptable limits (see Appendix 2) can be associated with:

- Pre- and post-weaning diarrhoea
- Elevated non-specific mortality rates
- Mastitis/metritis/agalactia in sows
- Poor growth
- Discharges, increased levels of returns and spontaneous abortion in breeding sows (Bishopton clinical archive, 2016, unpublished)

**What influences microbiological quality of water as delivered to pigs?**

A high microbiological load in water as drunk by pigs will be affected by a number of factors:

- High microbiological load at source, most likely from a contaminated borehole supply
- Contamination in primary storage
- Contamination during distribution
- Contamination in secondary storage
- Contamination at drinking points

**Where is water with a high bacterial load most likely to have effects on my pigs, and what might I see?**

Pigs at weaning are subjected to multiple stresses including a significant change of diet, mixing of litter groups, movement and rehousing so that their immune function is compromised. Delivery of clean water at this time is essential good practice. Water intake at weaning is also low in relation to the volume of plumbing systems, creating slow flow rates, while environmental temperatures are often high to prevent chilling of pigs. This creates ideal conditions for bacterial multiplication in slow-moving, warm water. High bacterial challenge from contaminated water at this time can lower growth rates, decrease appetite and result in scour depending on contamination type.

Sows in lactation drink high amounts in relation to body size, and lactation creates major physiological demands. Poor water quality at this time will limit appetite and lactation performance, which can result in sow mastitis, vulval discharge or scour developing in their litters.

### 4.4 Management and cleaning of water systems

The level of microbiological contamination of water provided to pigs in the UK is higher than desired, and on a number of farms will be contributing to production and health issues. Testing of water at point of consumption should be undertaken as part of any investigation into such issues. Correct, regular sanitisation of water systems will help prevent these problems and maximise profitability, based on cost benefit analyses that will be farm-specific. The UK poultry sector has adopted routine water hygiene symptoms with considerable success, helping to manage the prevalence of *Salmonella* spp., improving FCRs and contributing to better-controlled antibiotic use.

The benefits associated with provision of clean water can include:

- Improvement of feed conversion efficiency (FCE) up to 0.3
- 30–50g/day increased daily live weight gain (DLWG)
- 2 per cent reduction in weaning mortality

For a useful resource, consult the AHDB cost of production calculator.

**Table 12. Examples of the types of potential contaminants and their sources, and suggested counter-measures to address the source of the contamination**

| Contaminant/hazard | Source of contamination | Counter-measures |
|---|---|---|
| Chemicals<br><br>Including heavy metals such as cadmium, copper, molybdenum, arsenic and lead, as well as pesticides, nitrates and sulphates | Chemicals used in farming, forestry, industry, commercial premises or workshops | A risk assessment of the supply should be carried out to assess the potential for contamination, which will inform the level of testing required<br><br>If a hazard is identified or if a test contains microorganisms or chemicals above prescribed standards, there must be an investigation into the cause and |
| Microorganisms<br><br>Animal faeces, sewage from spreading or accidental leakage | Private water supplies drawn from land where animals graze or where manure is spread. Heavy rainfall or warm weather increases this risk | |

| | | |
|---|---|---|
| | | appropriate remedial action taken to reduce/remove the risk |
| Microorganisms<br><br>Cess pits or septic tanks | Discharge from cess pits or septic tanks | |
| Microorganisms<br><br>Ground water, vermin | The spring from which the ground water emerges or where it collects in the borehole or well. Vermin access to water storage facilities. | Wells and boreholes need to be protected, ie cased to prevent contamination leaking through the sidewalls.<br><br>Spring water reaching ground level needs to be cased from its point of exit from the ground all the way to its point of use (or into a storage tank)<br><br>Collection chambers/tanks should:<br><br>• Have watertight and vermin-proof walls and lids<br>• Be above ground level (tops only for chambers) to stop water from surrounding land flowing into them<br>• Be designed to stop animals and debris from entering them (eg overflow pipes or vents in chambers) or have mesh cover installed<br>• Be positioned a good distance away from any soakaway or drain |

*Adapted from Meat Industry Guide, Page 4, Chapter 3 – Water Supply, August 2015*

**Filtration**

The basic requirements are for simple filtration of the incoming water to remove gross debris, and then finer filtration to deal with excessive levels of mineral contamination, for example. Filtration and reverse osmosis are commonly used in the UK to clean up local water supplies. However, for most pig units supplied by ground-zone water, the target may be to provide in-line filtration and regular sanitising of the whole water system, with more suspect supplies requiring the addition of UV cleaning or nano-filtration. These are all areas where professional guidance and advice should be used.

High microbiological load at source may not be removed by filtration, though some nutrients capable of supporting further microbiological growth downstream of the filter will be removed by the process. Filters may actually become a site for bacterial growth and need regular maintenance.

**Ultra Violet (UV)**

Some borehole supplies attempt to use ultraviolet (UV) light sanitisation of source water, which is helpful but subject to limitations. Within the right range of the UV spectrum (100–400nm), UV radiation will destroy many microorganisms in a time-dependent manner but its effects vary according to penetration of the radiation into the organisms such as bacteria. Some considerations to bear in mind when using UV filtration are that they:

- Are not effective in turbid, 'murky' water (optimum 300–500mg/ml TDS)
- Are best suited to slow-moving, pre-filtered water flows
- Have impact only at point of application; there is no residual effect
- Are at best 99 per cent efficient

All of the above implies that bacterial contamination may exist downstream of UV cleaning of water supplies, unless the water distribution network is totally fit for purpose.

**Ultrasonography**

Ultrasound at a low kHz range can be effective for disinfecting water but needs to be used alongside another biocidal treatment (eg chlorine, UV, etc). When used with chlorine, it can reduce the amount of chlorine needed to achieve a biocidal effect.

However, owing to the equipment and set-up required, it has limited practical application on farm.

**Novel cleaning methods**

Work has been done which shows that using novel techniques including elemental silver paint or titanium dioxide photocatalysts can be effective for removing microbiological threats from water. However, these techniques have not been proven to be effective against all pig pathogens, and owing to the cost and equipment required, there is limited practical application on farm.

## 4.5 What is a biofilm and what is its significance?

Biofilm is a particular biological environment capable of supporting microscopic biological life that develops at the interface between any liquid and any solid. It is frequently noticed as the slime on the internal surface of any liquid container or pipe. Biofilms form through the attachment of certain microorganisms to solid surfaces, which then quickly develop a microscopic framework that attracts and protects other types of microorganisms including fungi, algae and bacteria. These can filter organic matter from the water around them to support their growth and even accumulate minerals such as calcium and iron to form part of the structure.

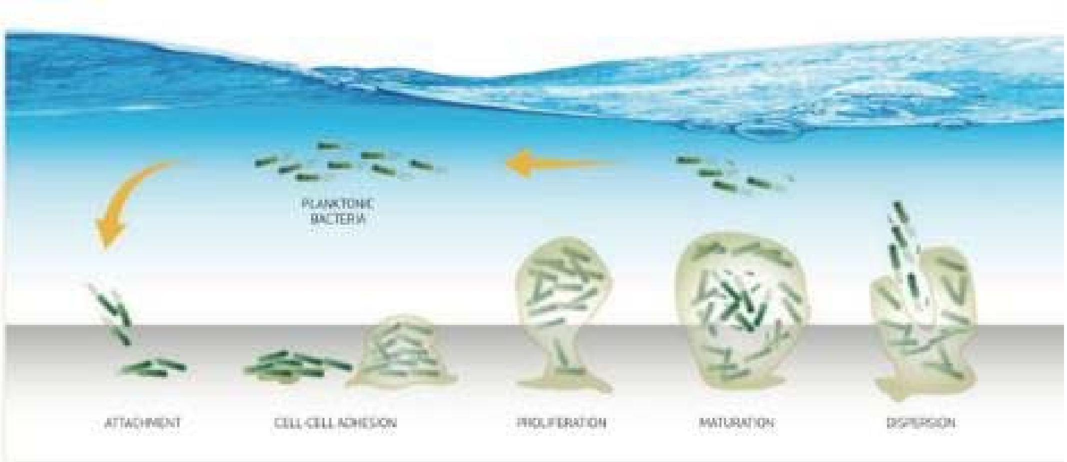


Figure 30. Graphical representation of biofilm development

Diagram courtesy of CEVA UK Ltd.

Growth of biofilm will always occur in water systems. Particularly, fungal organisms capable of contributing to biofilm are more likely to be found in low-temperature, ground-water sources, which are common in the UK.

Layers of biofilm build up at variable rates according to water type and its available nutrients, whether the water is still or fast moving, ease of attachment offered by smooth or rough surfaces, and ambient temperatures. The highest rate of biofilm deposits are observed at water temperatures between 15–25$^{o}$C (Donlan et al., 1994). This temperature range is most common in UK indoor housing and accentuates the need for continuous good hygiene within water systems.

Figure 31. Biofilm development inside a pipe

Biofilms can become long-term habitats for a very diverse population of mixed types of microorganisms and, once established, are difficult to eliminate, providing an ongoing source of contamination because particles consisting of aggregates of bacteria and mineral break off, and effectively seed the downstream areas.

The framework structure and depth of the biofilm will provide physical protection of organisms against disinfectants such as chlorine, while some of the bacteria can attack the lining of metal pipes, increasing corrosion.

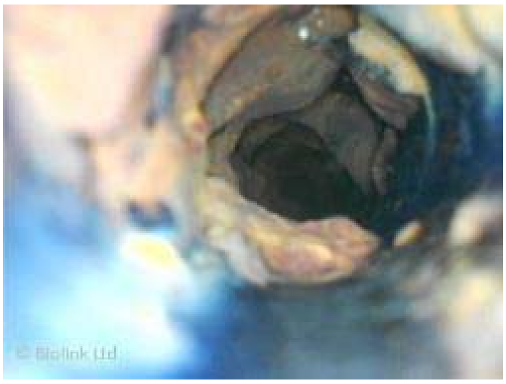

Figure 32. Biofilm lining the inside of a water pipe

The complex mixture of bacteria that are present means biofilms have been shown to harbour known pathogens such as *Legionella* spp., *Salmonella* spp., and also bacteria common to the environment of pig units such as *E.coli* and *Pseudomonas* spp. (Wingender and Flemming, 2011). These bacteria may lie dormant in biofilm, and can then be poorly detected by common sampling techniques.

Bacteria enter water systems through leaks, joints and any air gaps such as those deliberately present in header tanks. High-risk areas for developing biofilm include:

- Standing or slow-moving water
- Buildings that are empty for a period
- Dead-end pipe runs
- Horizontally curved runs (slower passage of water in certain segments)
- Joints that create eddies
- Intermittent water flow, combined with long periods of standing at warm ambient temperatures such as the final drop pipe to a weaner nipple drinker.

The nature of pigs is such that their mouths are frequently in contact with faecal contamination, and drinking can then inoculate any form of drinker mechanism with bacteria able to join the biofilm layer.

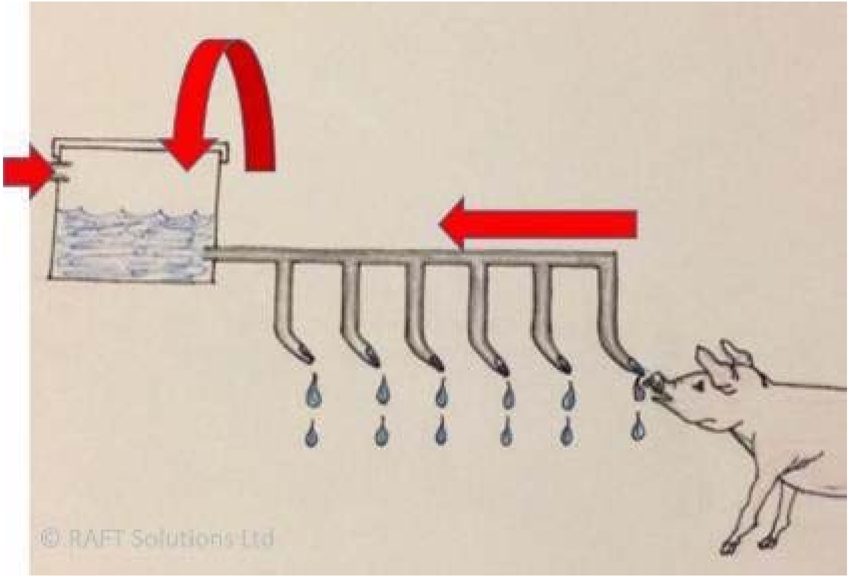

Figure 33. Schematic representation of how bacterial contamination may get into header tanks to create biofilm

The presence of biofilm in extended pipelines is often hidden, and while pipelines can be physically interrupted to check for its presence by visual inspection and feel, a single check of the output of water from a system cannot always be used to assess microbiological quality. This is due to the intermittent shedding of bacteria from the biofilm and also because not all bacteria are in a state where they can be identified. It is suggested that examination of the internal pipework of pig units is carried out on an annual frequency after any initial investigation, and more frequently if pig gut health is compromised by an unknown cause.

Figure 34. (left) and Figure 35. (right) Biofilm presence in a header tank

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Figure 36. (left) and Figure 37. (right) Contamination found within the pipework demonstrating the presence of biofilm

Once developed, biofilms can subsequently become mineralised within the water delivery system. The process of mineralisation of biofilm will happen more readily with a water supply that is high in calcium or magnesium salts, dissolved iron or manganese. Iron in particular can be used as an energy source by certain bacteria.

Build-up of biofilm on internal surfaces will reduce the effective diameter of a pipe and potentially reduce water flow rates.



Figure 38. (left) Clean pipe and Figure 39. (right) Build-up of biofilm in a pipe

Use of any water additive will modify the biofilm layer that comes into contact with it. Some sugars (added to make medication more soluble), vitamins and some organic acids can be used as energy sources by the bacteria for biofilm growth. Such additives may be metabolised by biofilm, causing a 'bloom' of bacterial and biofilm growth, which can break free of attachment and then flow to block drinkers. The depth or thickness of biofilm will protect organisms in the deeper layers of the film from the effects of antibiotics or water sanitisation such as chlorine and peroxide. Ultimately, it is key that biofilms are monitored and managed as the more biofilm present, the less efficient any cleaning process will be.

## 4.6 The importance of a good-quality water supply

Clean water is an absolute requirement of healthy livestock production. However, the continuous delivery of clean water requires a positive management of resources and a robust maintenance strategy. The payback of such investment is via achieving the target of healthy pigs and efficient production.

**How do I provide clean water to my pigs?**

Water should initially be checked at source for microbiological contamination, as well as at any exit from primary source storage. Large storage tanks should be emptied at least annually and sanitised using a suitable water disinfectant, depending on the type and degree of contamination observed. Heavy sediments need to be physically removed from tanks, and consideration should be given to treating water further on entry and certainly on exit from these tanks if mineral or microbiological limits are exceeded.

Pipes between primary and secondary storage should be disrupted and examined for gross contamination. As part of routine annual maintenance, a water treatment based on removing scale/iron/manganese build-up and biofilm in these areas should be considered. Depending on the extent, a system deep clean could be needed to restore the internal surfaces of the pipes to their original surface. The degree of roughness of the internal surface of pipework has a greater influence on the ease of cleaning than the type of pipe metal itself.

Secondary water storage tanks should be sanitised with each fill of the building they supply, along with the pipes and drinkers they feed. Please see Section 6 for the periodic clean procedure and Appendix 11 for a cleaning protocol. An ongoing and permanent chemical additive may then be required if source water is contaminated or health challenges are present in these buildings.

Treatment of continually occupied buildings or buildings where animals are present is possible but requires care and suitable chemical agents. High levels of water sanitisers will free large quantities of scale and biofilm that can block valves or drinkers and result in water deprivation unless rapidly cleaned. Lower concentrations of some chemicals are well tolerated by pigs and can slowly remove biofilm without detriment to the pigs or to water flow – see Section 4.4.

Table 13 and Table 14 show examples of cleaning down water systems on two UK pig units during a water quality surveillance project (Robertson, 2006). The target total viable counts (TVC) were arbitrarily set at 2,000/ml in the absence of any clear guidance for livestock water quality at that time. The project demonstrated two clear facts:

- some water supplies were not acceptably clean
- cleaning dirty water supplies up to the point of delivery was not difficult

Table 13 shows results from a unit where there were concerns about river water contaminating a nearby borehole supply when the finishing house water sample was found to be above target for

*E.coli*. The borehole supply was 20m from a river that was heavily contaminated with slurry run-off after heavy rain. While the river water was dirty, this was not the cause of the poor water quality in the finishing house, as demonstrated by clean water samples from the borehole and the main farm bulk water tank. Cleaning of the finishing house water supply was achieved with simple application of a commercial sanitiser throughout the pig unit supply pipework and header tank.

**Table 13. Example of a finishing house with poor water quality**

| Location | TVC (/ml) (target <1,000/ml) | *E. coli* (/ml) (target – 0/100ml) |
|---|---|---|
| **Finishing house** | 1,650 | 310 |
| **River** | 13,000 | 4,300 |
| **Borehole** | 2 | 0 |
| **Bulk water tank** | 3 | 0 |
| **Finishing house (cleaned)** | 0 | 0 |

Table 14 shows the water quality results before and after cleaning from flat-deck water delivery systems that had not previously been cleaned for more than one year.

**Table 14. Example of in-line sanitising of a water delivery system**

| Location | TVC (/ml) (target <1,000/ml) | *E. coli* (/ml) (target – 0/100ml) |
|---|---|---|
| **Flat deck room #1** | 20,100 | 50 |
| **Flat deck room #1 cleaned** | 0 | 0 |
| **Flat deck room #2** | >20100 | 9500 |
| **Flat deck room #2 cleaned** | 0 | 0 |

## 5 How to choose a drinker to aid correct water provision

The purpose of the drinker is to present sufficient-quality water to the pig. When choosing drinker, a number of factors need to be considered:

- Suitability with regard to the drinking behaviour of the pig – accessibility, ie type, position (height, angle), number, etc
- Provision of correct flow
- Maintenance of good water hygiene
- Siting of the drinker within the pen
- Cost
- Water wastage
- Routine maintenance

For the purposes of this report, drinker types will be divided into:

a) **Valve drinkers**, which require the pig to open the valve, with the pig then drinking directly from the flow. These can be further divided into 'nipple drinkers', where the pig is required to only move a 'nipple' to one side to allow flow, 'bite drinkers', where the pig is required to bite onto the mechanism to open the valve, and 'button drinkers', where the pig has to push onto the valve to allow flow. Valve drinkers may be located inside feeders.

b) **Bowl drinkers**, which allow the pig to drink directly from a pool of water, which may provide sufficient space for several pigs to drink at once. A float valve may be used to maintain a relatively constant water level or nipple or button valves may allow pigs to fill the bowl themselves.

c) **Trough drinkers or water troughs** also allow several pigs to drink from a pool of water and are usually floor-mounted, and self-fill by means of a float valve. Trough drinkers are commonly used for lactating sows, with the trough self-filled by sow-operated valve drinkers. They may also be used for feeding – either as a common space or with a division separating feed and water.

Piglets and newly weaned pigs find water more readily if it is presented in a bowl or trough and often learn to drink through imitation of their litter or pen mates. The preference for bowls continues through the growing stage but since pigs avoid drinking water that has been fouled by faeces, if a bowl becomes fouled, pigs will change their preference to nipples. Each individual pig *does* have to learn how to operate each drinker type.

Pig production in terms of ensuring optimum feed intake is more dependent on the available water provided by each drinker – principally governed by flow rate in valve drinkers – than the drinker type, given similar levels of hygiene and access are provided. Inadequate flow will limit water intake but excessive flow will lead to wastage of water, and add to slurry or muck handling costs.

While the choice of drinkers has an impact on overall water use, the most critical aspect of the positioning of valve drinkers is their height and angle relative to the pig using it, so that the flow of water through the mouth and down the throat is optimised and wastage minimised.

To aid correct water provision:

- Check height and angle of drinker is suitable – see Table 15
- Encourage pigs to stand facing straight onto valves and not stand at an angle, which risks spillage from the side of the mouth
- Locate drinkers against walls or use separator bars, flanges or wings around drinkers, to help protect and prevent pigs accidentally opening valves
- If possible, mount drinkers over or next to dunging areas, which will usually be the coldest part of a pen
- A step or angled plinth will help achieve the correct drinking position from open bowls or troughs while reducing the risk of fouling

Table 15. Ideal placement of nipple drinkers

| **Location** | **Angle from the wall** |
|---|---|
| Shoulder height | $90^o$ |
| 20% above the shoulder height | $45^o$ |

*Source: Gonyou, 1994*



Figure 40. (left) – incorrect, and Figure 41. (right) – correct. Examples of how drinker placement is vital to ensure pigs are encouraged to drink properly from them


Figure 42. Example of how an angled plinth can help to encourage the correct drinking posture and reduce risk of fouling in the water delivery system

There can be a difference in water wastage of 30 per cent between different types of drinker, with bowls wasting less than nipple-valve drinkers, and bite-valve drinkers also wasting less than nipple-valve ones, when height alignment and flow rates are optimised and similar (Magowan et al., 2007). The measured difference between water wastage of one type of nipple drinker compared with a bite drinker was 34.8 per cent over a one-year period (Brethour et al., 2006), equivalent to approximately 350l/day in a group of 200 finishing pigs, or 20,000l (20m$^3$) during the finishing period.


Figure 43. Example of a bite-valve and a nipple-valve drinker

Pigs provided with bowls or troughs take fewer drinks, to consume the same amount of water but spend less time actually drinking, than those using valve drinkers. The correct placement of bowls will also help to encourage water intake. The placement of drinkers is necessary as well to encourage intakes, and when those are placed correctly, pigs are seen to interrupt feeding more often to access nipple-valve than bowl drinkers. Given the close association between feeding and drinking behaviour, all drinking points should be sited relatively close to feeders and this is probably more

important where nipple valves are used, when the nearest valve drinker should be the distance of two feeder spaces away. Too close an arrangement of feeders and bowls or troughs risks pigs dropping uneaten food into volumes of water with subsequent fouling risk.

As a minimum, the separation *between* drinking points should be equivalent to the shoulder width of the heaviest pig within any particular pen.

The height at which drinkers should be mounted depends upon its angle of presentation and the size of the pig using it. For valve drinkers pointing straight out at 90$^{o}$ to the wall, the correct placing is at the shoulder height of the pig, whereas for valves orientated downwards at 45$^{o}$, the valve should be 20 per cent above shoulder height to achieve a slight lift of the head – see Table 14. Heights should be adjusted as pigs grow, targeting the average size of the pigs in the pen.

Figure 44. Example of a height-adjustable drinker

Pigs should drink from a bowl with the head slightly lowered. If a bowl is mounted too high, the pig bites the lip of the bowl while drinking and spills some water, whereas if too low, the risk of fouling increases. The suggestion is that the height of a bowl should be 40 per cent of the height of the smallest pig.

**Wet/dry feeders**

Water may be provided via a nipple, bite or button valve sited within the feeder. Water use is reduced by 10-15 per cent compared to a bowl drinker and intake of dry meal can be increased by 5 per cent compared with a dry feeder and a separate drinker. Some of this reduction will be due to less

wastage. However, an additional drinking point per pen above the normal specification for pigs per drinker and at a site away from the feeder is recommended and has been shown to increase growth.

Figure 45. Example of wet/dry feeder
*Source: Crystal Spring*

Irrespective of feeder type, routine daily stockman tasks should include a twice-daily check of water provision to each pen of pigs to assess presence of water, correct flow and absence of leaks or drips from valves. A drip every second equates to over 1.5$m^3$ (330 gallons) of water per drinker per year. Flow rates at individual drinkers can be affected by blockage of the filter (Figure 46) at the rear of each valve, limescale or biofilm build-up, corrosion or other foreign bodies. Filters should be checked regularly, and any repetition of blockages should lead to a check for the source of the blockage material, such as biofilm or mineral deposits. Flow rate targets are shown in Table 5 in Section 2.6.

Figure 46. Filters can be found internally within the top of some drinkers

## 6 Why should I clean my water?

Clean water and water systems prevent the exposure of naïve pigs to pathogen carry-over or transfer between pens, rooms or batches within otherwise 'all-in, all-out' hygienic pig flow systems. Infected and pathogen-shedding pigs use drinkers and thereby introduce contamination into the drinkers and pipelines where they can remain viable for variable periods depending on the pathogen (see Table 11 in Section 4.3) but which can certainly exceed the downtime between consecutive fills of pens or buildings. Uncleaned water systems have been associated with repeated episodes of clinical disease such as PRRS, Swine Dysentery, *Salmonella* spp., *Mycoplasma* spp., *Streptococcus suis* and *Actinobacillus pleuropneumoniae* (APP).

Pigs root within the toilet area of their pen and inevitably contaminate drinkers with faecal organisms such as *E.coli*. These bacteria possess mobile, hair-like flagella, which allow such bacteria to move independently from the drinker into pipelines where they become an established part of the biofilm coating pipes. Intermittent shedding of these organisms occurs. These are then re-ingested and provide a constant challenge of viable bacterial culture – this can be a factor in both pre- and post-weaning diarrhoea outbreaks.

Constant exposure to water-borne bacteria acts as an ongoing challenge to the immune system in any pig. Immune system activation acts to initiate mediators in the body, which leads to systemic reactions that reduce appetite, growth and food conversion efficiency, meaning that otherwise healthy looking pigs experience a loss of growth. It appears that, in some instances, high levels of contamination of water provided to pregnant sows has been associated with increased levels of returns and abortion, presumably through inflammatory pathways. Other reports have occurred of cases of MMA complex (mastitis/metritis/agalactia) improving once biofilms present in farrowing house header tanks and pipelines have been sanitised. In all of these scenarios, the presence of contaminated water leads to a reduction in the production efficiency of the unit.

Build-up of internal biofilm can dislodge and block pipelines, resulting in acute water deprivation or more chronic flow rate issues.

For disinfectants to work effectively against target microorganisms (see Table 16 for examples), the water primarily has to be clean, with a low organic matter content. It is suggested the total dissolved solids (TDS) levels in the water are below 1000ppm and the water visibly clean before being used to dilute disinfectant for application to surfaces (refer to Appendix 8 for dilution rates of specific disinfectants on a range of porcine disease organisms).

**What water sanitisation products will work best?**
Water may have to be cleaned and disinfected at source, and clean water should not be allowed to become contaminated by passing through contaminated water infrastructure on farm.

The available evidence is that most farms need to actively manage water quality and use cleaning routines to maintain target quality levels. A range of chemicals exist to disinfect water and remove scale and biofilm dependent on the different challenges of the water supply, and current state of the water infrastructure.

The most reliable source of factual and up-to-date information on cleaning products exists on the product datasheets, available online and from reputable dealers.

**NB: All chemicals have a hazard warning, which should be read, understood and applied. Information and records should be available to all users on site. See Health and Safety note in Appendix 10.**

Sanitisation of water is one of the steps that may be required on farm so that clean water is provided to all pigs. Gross organic matter is typically removed by filtration and sedimentation (Section 4.1) and there are multiple sanitisation methods available to reduce TDS (see Table 15). As stated above, it is important that the gross contamination and TDS levels are at an acceptable level to ensure that the cleaning products subsequently used achieve their optimum effects.

Chemicals are used around the world to help provide clean water, but they naturally have different properties from one another, and the optimum product for any one farm requires knowledge and assessment of needs. Table 16 shows examples of which pathogens are targeted by different chemical products. Advice should always be sought to ensure the correct product is selected for the needs and set-up on your farm.

**Chlorination** is frequently employed as a method of water sanitisation. It relies on the effects of hypochlorous acid to kill bacteria and other microorganisms. Chlorine is inactivated by organic material and will fail to penetrate layers of biofilm, so cannot be used as an initial cleaning agent for systems. Its disinfectant property decreases with distance from its insertion into a system and it can be corrosive to metal, seals and gaskets with prolonged exposure. It is more effective in acid conditions, yet a lot of borehole water is slightly alkaline. It should however be recognised that when used in combination with acidified water, there is a risk of chlorine gas production, which is poisonous and can be harmful to pigs and people. It is therefore advised that this process is not carried out when pigs or personnel are in the building.

**Chlorine dioxide** is a gas, usually generated locally on site from a mixture of chemicals including calcium hypochlorite, which, when dissolved in water, is more stable than chlorine and has a longer duration of disinfection activity, up to 48 hours depending on original water quality. With ongoing use, it has the ability to remove a non-mineralised biofilm. It is more effective when used in closed systems with no exposure to the air, hence it will become less effective if allowed to stand in water (eg in a header tank) for any period of time.

## Table 16. Sanitisation methods available for water

| | Liquid Organic Acid Mixtures eg Lactic | Acid-type water disinfection | Chlorine | Chlorine Dioxide | Stabilised Hydrogen Peroxide |
|---|---|---|---|---|---|
| **Descaling effects ie limescale removal** | Will remove and prevent build-up of limescale | Will remove and prevent build-up of limescale | No marked effect on removal of limescale | Only mild effect and not recommended for limescale removal alone | Only mild effect and not recommended for limescale removal alone |
| **Iron deposit removal** | Will assist removal of iron deposits | Will assist removal of iron deposits | No marked effect on removal | No marked effect on iron deposits | No marked effect on iron deposits |
| **Manganese deposit removal** | Will assist removal of manganese deposits | Will assist removal of manganese deposits | No effect on manganese deposits | No marked effect on manganese deposits | Removes manganese deposits |
| **Ongoing water disinfection** | Effective against some bacteria. Can promote algal bloom | Effective against some bacteria. Can promote algal bloom | Poorly effective in contaminated or alkaline environments. Less stable | Yes at low concentration. More stable than chlorine alone | Yes at low concentration. Safe for pigs to drink |
| **pH considerations** | Can be drunk by pigs at pH4 | Can be drunk by pigs at low concentrations | Greater concentration needed in water >pH7. Synergistic effect with acidity – Care as can result in production of chlorine gas. | Synergistic effect with acidity | N/A |
| **Compatibility with medication** | Care – seek medication manufacturer's advice | Care – seek medication manufacturer's advice | Care – seek medication manufacturer's advice | Care – seek medication manufacturer's advice | Not recommended for use with medications – remove and flush before use |

Table 17. Antimicrobial products applied to control biofilms formed by bacteria

| Treatment | Biofilm Type |
|---|---|
| Ozone, commercial chlorinated sanitiser | *P. fluorescens/Acaligenes faecalis* |
| Benzalkonium chloride, hexadecyl trimethylammonium bromide, sodium hypochlorite, peracetic acid, hydrogen peroxide, O-cresol, phenol | *E. coli* |
| Chlorine, peracetic acid, peroctanoic acid | *L. monocytogenes* and *Pseudomonas* mixed biofilms |
| Chlorine dioxide-containing sanitiser | *B. cereus/P. fluorescens* single and mixed biofilms |
| Chlorine | *E. coli* |
| Chlorine-alkaline solution, low-phosphate buffer detergent, dual peracid solution, alkaline solution, hypochlorite | *L. monocytogenes* |
| Sodium hydroxide, commercial alkaline cleaner | *P. putida* |
| Chlorine, ozone | *P. fluorescens, P. fragi* and *P. putida* |
| Chlorine, hydrogen peroxide, ozone | *L. monocytogenes* |
| Glutaraldehyde, ortho-phtaldehyde, hexadecyl trimethylammonium bromide, sodium dodecyl sulfate, chlorine solution, sodium hydroxide | *P. fluorescens* |
| Sodium hydroxide, nitric acid | *Mixed species* |
| Chlorine, chlorine dioxide, commercial detergent | *B. cereus* and *Pseudomonas* spp. |
| Hydrogen peroxide, sodium dichloroisocyanurate, peracetic acid | *Staph. aureus* |

*Source: Simoes et. al., 2010*

**Acids** fall into two categories – single acids such as acetic, and organic blended acids such as formic, lactic, propionic and other mixes. Both types will help remove limescale and will modify biofilm but will not eliminate acid-tolerant microorganisms, and may even promote growth of some slime moulds. In **concentrated** form, acids can be corrosive to metals, rubber, some plastics and concrete and are a hazard to farm personnel handling them. Initial cleaning of old water systems with mixed metal pipework can result in pipework failure at joints. Seek professional advice before using new products.

At the time of writing this report, the authors scoped available evidence to enable a cost benefit analysis of adding a variety of acids to water. However, inadequate published work was available.

**Peracetic acid** is a mixture of acetic acid and hydrogen peroxide that oxidises microorganisms, resulting in rapid deactivation. The effect is hardly influenced by organic material present in water but is less effective at low temperatures and in neutral or alkaline water (pH8–9).

**Hydrogen peroxide** is a powerful oxidising agent that degrades into non-harmful products. It has reasonable disinfecting properties, with activity against a broad range of bacteria, but it cannot penetrate deep layers of biofilm. Modified compounds of hydrogen peroxide can however help to provide longer-lasting disinfectant ability. Venting of the gas produced by the use of hydrogen peroxide should however always be considered during use, and care should be taken to prevent contact with the skin.

**Mixtures** of compounds are available commercially that combine the cleaning and disinfection properties of the above, which are suitable to remove scale and render microorganisms within biofilm inert, yet are relatively safe and convenient to handle.

The correct use of cleaning products requires accurate concentration of the active ingredients to be administered regularly to the water flow; this in turn requires some form of dosing equipment such as proportional pumps – see Section 7. Health and safety information for all products is freely available and must be provided to the user.

In some cases, pipework may be so scaled and contaminated that the most cost-effective method is to substitute it with smooth internal bore replacement pipe and then perform an ongoing sanitisation programme. Costs of replacement parts for water systems are outlined in Appendix 9 .

**Please ensure you refer to the manufacturer's guidance documents for product data and relevant health and safety information of each product.**

## 6.1 Practical aspects of deep cleaning of water systems

When cleaning a water system, you should always:

1. Consider a site survey
   a) Check the full layout of existing pipes from source to each drinker
   b) Identify/eliminate any dead ends, unused pipework, or slow-flowing areas
   c) Mark any static water storage for particular attention, such as removal of tanks and deep internal clean
   d) Break into pipework at various places including the end of line in each house and determine the extent and type of sediment present within the pipework system

2. Take a sample of water at source to assess organic matter levels, pH, hardness and iron/manganese levels, which have most effect on water sanitisation
   a) If excessive levels are present, then treat direct from source via filtration, and/or ion exchange water softeners and/or acidification. Target TDS levels are shown in Appendix 1

3. Test water at source for microbiological quality, sampling after preliminary treatment
   a) If excessive levels of microbiological contamination are found, then sanitise water constantly at a suitable maintenance level – consider stabilised hydrogen peroxide or sulphur dioxide systems. See Appendix 2 for target levels

4. Test four samples for microbiological levels taken from around the farm
   a) Either from the far end of waterlines (ideally from pipework and not from drinkers) if houses are occupied and their drinkers are in use, or from drinkers in empty rooms that have already been washed, but prior to any surface or water disinfection.
   b) Allow water to flow for a few seconds before sampling to remove any gross external contamination
   c) Take care to avoid associated contamination of the samples taken – see Appendix 3
   d) As a guide, consider prioritising the farrowing and weaner accommodation, older buildings and buildings at the end of the farm water network

5. Determine the best position to locate water sanitisation equipment, considering the various water dosing options with regard to flows and pressures

6. Bear in mind that heavily contaminated areas may require 'shock dosing' with a high concentration of a suitable chemical. This process may dislodge material from pipes sufficient to block drinkers where there are pigs, so make sure pigs continue to receive adequate water flow rates if expected to continue to drink. Only use suitable chemicals if pigs are expected to drink treated water
   a) Shock dosing is suitable to treat specific areas of the unit, such as separate farrowing rooms and weaner areas, which are run 'all in-all out', with treatment carried out during the empty period on isolated waterlines. This may form part of the routine room hygiene programme to ensure clean waterlines are maintained

7. Carry out an ongoing maintenance level of dosing depending on initial water quality,, usually at a lower level of concentration than the 'shock dosing'
   a) A check of the concentration level of sanitiser actually present at the drinker should be performed regularly. Test 'dip' strips are available for some chemicals to assess this.

8. Remember that the presence of sanitisation chemicals will have an effect on any further products included in the water, such as antibiotics and vaccines administered through the water supply. In case of any doubt, contact the product manufacturer to confirm compatibility between products. However, water sanitisation should always be performed **before and after** administering products via the water, to reduce the risk of interactions with the product within the water

system. A system clean-down with sanitisers may be required where treatment-additive products promote high biofilm bloom.

9. Consider using flush valves or taps at the end of lines to move high flows through pipework to assist in the flushing-out of displaced sediments, or residues of medication.

## 6.2 Acidification of the water supply as a specific management practice to aid disease control and feed intake

In any pig, gastric secretions create an acidic environment in the stomach that helps to eliminate pathogens ingested with feed and causes the upper small intestine of the pig to be naturally acidic. Highly acidic conditions are inhibitory to the multiplication of many bacteria especially *E. coli* and *Salmonella spp*. and so naturally acidifying diets such as fermented wet feed and high barley inclusions within coarse meal diets are associated with good intestinal health of the grower/finisher pig.

The beneficial use of acidified feed for management of *Salmonella* spp. can be replicated via the administration of organic acid mixtures via the drinking water. The mode of action involved in bacterial inhibition is that non-dissociated organic acids can potentially enter bacteria, where they dissociate as a result of the higher pH in the cell. This action lowers the bacterial cell pH and affects protein and DNA synthesis. The effect appears most marked in Gram-negative bacteria such as *E. coli* and *Salmonella* spp..

A number of pig producers in the UK have introduced water acidification, initially as a means of controlling *Salmonella* spp. However, they have found other health benefits especially in terms of reduction of incidence of diarrhoea, with the most marked improvements seen in newly weaned animals.

Acidification via feed or water appears to improve protein digestion and has been demonstrated to reduce the incidence of diarrhoea. This can subsequently reduce the need for veterinary interventions as fewer numbers of weaners fail to thrive around the critical important time of weaning. The palatability of acidified water compared to plain, possibly non-sanitised water appears to be improved with a parallel improvement in feed intake and food conversion efficiency. This contributes to a positive cost benefit ratio especially in the initial four weeks post-weaning. Similar health benefits can be seen in heavier pigs but the relatively cheaper diets fed at this stage, coupled with their higher intake of acidified water, may fail to show a positive cost benefit.

| |
|---|
| Some practical issues have been found with water acidification:<br>• The ratio of inclusion of organic acids should take into account the initial pH of the water source and be calculated to give a pH of water as drunk by the pig of pH4 for best effect in terms of enteric disease control<br>• A handheld pH meter or pH dip test strips should be used at the point of water delivery to the pig to assess correct acidification regularly<br>• The concentrated acid stock solutions are very corrosive to equipment such as proportional dosers and require stringent personal protection precautions to be observed by those handling them – see Appendix 10. |
| • Acidified water is corrosive to ferrous or brass pipework, valve fittings (eg ballcock valves) and troughs, meaning that replacement with stainless steel or plastic alternatives would be necessary. Concrete floors and walls are rapidly eroded by spilt acidified water. Around 50 per cent of farms report the formation of fungal 'blooms' within header tanks and pipes when using acidified water. The fungi metabolise components of the organic acids and the resultant blooms can block drinkers and reduce flow rates. |

| |
|---|
| **Some medications developed to be delivered via the water system are incompatible with low pH and advice should always be sought from the manufacturer or specific product guidelines before any concurrent use with acidified water.** |

Owing to its effect in displacing biofilms and limescale, the first use of acidified water in a not previously regularly sanitised water system will displace solids including rust and biofilm that can block nipples similar to the situation when fungal blooms occur. The best solution for both problems is to use a shock clean (see Appendix 11) routine before use of acid as a management tool for *Salmonella* spp. Control for example, and then revert to a standard cleaning routine regularly after a period of use of acidified water. The cleaning routine for the water system should always be farm-specific.

Acidified water is compatible with other methods of water sanitisation such as peroxidation or chlorination, which relies on the production of hypochlorous acid for its disinfection effects. For example, chlorine dioxide is a more effective sanitiser in low pH water than neutral pH, at the same concentration of product. Addition of chlorine-based products to acidified water can also result in the production of chlorine gas, which is potentially harmful to both pigs and people, so care must be taken over its use.

# 7 Administering products into water systems

Additives need to be administered via water systems for multiple purposes including medication, nutrition and water sanitisation. The scale of this need can vary from small groups of hospital pigs requiring extra vitamin and electrolyte support, to whole farm water infrastructure that requires ongoing sanitisation. Each administration of product however requires an accurate concentration of the additive to be achieved in the water at its point of effect. This can only be achieved with accurate calculation of volumes and flow rate in the target water system as well as accurate and consistent administration of the product into the water system.

The health and safety requirements of all products should be clearly understood – see Appendix 9.

## 7.1 Manual dosing

Manual dosing can be conducted in individual bowls and troughs – which are not connected to the mains supply - used by small numbers of pigs (eg within hospital pens) but this is labour-intensive and not suitable for larger-scale administration into pipeline systems. This method allows wide variation in dosing frequency and concentration and carries the potential risk of introducing foreign material into the vessel used. However, this system can be achieved with very little capital outlay.

NB: When using independent bowls and troughs for dosing, ensure the mains supply to the pens is switched off, so pigs only drink from the medicated supply.

## 7.2 Direct dosing/batch mixing

The most common historical method of administration of medicines was via direct dosing into secondary building/room-specific storage tanks or header tanks but this has a number of drawbacks such as:

- Header tanks that are accessible to people to add medications may be poorly sealed and are often already contaminated with biofilms and other debris. This may reduce the efficacy of any added medication
- Ingredients of some medications or even the medications themselves can be used as energy sources by bacteria or fungi already present in the tanks or the pipelines, which in turn risks development of microbial blooms. These may have adverse effects on water quality, its supply or pig health. This can cause an effect throughout the water delivery system, but is of most concern where large volumes of stationary water are found, where microbes can have prolonged exposure to the ingredients (eg header tanks)
- The volume of water within header tanks is constantly depleted and replaced as pigs continue to drink from them. Therefore, unless the water supply to the tanks is turned off after medication is added, the concentration of medication varies widely but always becomes more dilute until a further top-up bolus of medication is added. It is vital to

accurately calculate the real volume of water in a tank, and not the volume of the tank. This will ensure that the medication is mixed to the correct concentration. See Appendix 7 for a guide on how to calculate the volume

**Turning off the supply of water to the header tank to allow more accurate dosing of the tank risks a dangerous interruption in supply of water to the pigs.**

- The overall volume of a typical header tank is usually insufficient to hold more than a few hours of water for a given group of pigs, meaning that there is often a need to add medication on a frequent and inconvenient basis. The dosing interval will be specific for each product, and so the product guidelines should be consulted for further information to ensure the correct concentration of product remains in the header tank at all times. This may require administration of the product during unsocial hours, despite the fact the majority of water consumption will follow the recognised diurnal pattern of drinking behaviour
- Header tanks are frequently raised to an inconvenient height or even situated over occupied pig pens, meaning that climbing to access them and administer product constitutes a personal safety hazard for stockpeople

All of the above factors mean that manual addition of products to tanks may compromise accurate and responsible use of medicines especially.

**ALWAYS CHECK WATER SUPPLY TO ALL PENS HAS BEEN RETURNED TO ITS CORRECT SETTINGS AFTER DOSING PROCEDURES HAVE TAKEN PLACE.**

### 7.3 Proportional dosing pump

The most accurate method of administering products into water is via a proportional dosing pump, which measures a given water flow and adds a suitable additive, usually in the liquid state, into the flow at a set proportion. There are two main types of proportional pump – the water-powered type and externally powered, peristaltic pumps.

- Both dosing pump types require measurement of the water flow rate at point of delivery
- There is a requirement for a minimum water flow for effective operation of dosing pumps, dependent on type of pump – see Table 18
- All pumps have a maximum safe operating flow rate
- All pumps can be damaged by excessive water pressure
- All pumps need to operate between the minimum and maximum limits in order to deliver accurate dosing proportions
- The impact of corrosive chemicals on pumps must be considered

**Table 18. Examples of proportional dosing systems available**

| Product | How the system works | Operating pressure | Water flow range | Injection range | Dosing accuracy | Lower end |
|---|---|---|---|---|---|---|
| **Dosatron (Hingerose Ltd)** | Concentrate pulled into pump and mixed with incoming water | 1.5–120 psi (model-dependent) | 4.5–9,000l/h (model-dependent) | 0.2–2% (model-dependent) | | Model-dependent |
| **AquaBlend (Hydrosystems)** | Concentrate pulled into pump and mixed with incoming water | 5–90 psi | 9–2,500l/h | 0.78-1% | +/- 10% of ratio | Fixed/ adjustable |
| **Select-480 (Select Dosing Systems)** | Peristaltic pump action. Prevents product coming into direct contact with pump mechanism | 30–44 psi max. | 400–25,000l/h (ratio-dependent) | 0.001–5% (standard range – others available) | >95% | n/a |
| **Select-640 (Select Dosing Systems)** | Peristaltic pump action. Prevents product coming into direct contact with pump mechanism | 29 psi max. | 400–25,000l/h (ratio-dependent) | 0.0025–5% (standard range – others available) | >95% | n/a |
| **Stenner Dosing System (Quill Productions)** | Peristaltic pump action. Prevents product coming into direct contact with pump mechanism | 80 psi max. | 0.7-4.7 l/h | 0.005–3% | +/- 2% reproducibility | n/a |

It is normal to fit either type of dosing pump adjacent to the main water flow with an isolating divert system constructed to allow water to flow untreated if necessary. This makes it easy to remove the pump for re-siting or maintenance.

**Water-powered proportional** pumps are pressure-driven and flow-dependent. They use an internal piston to create suction and draw up a given proportion of the liquid additive to be administered into the water supply. The amount administered depends on the volume of the piston chamber and can only be varied within certain boundaries depending on the model of pump chosen. The piston, its cylinder and parts of the pump itself are in direct contact with the concentrated product being administered and must be able to withstand its properties. Over time, moving parts will become worn, meaning examination and servicing is necessary with regular use. Most models are not suitable for very low pressure water systems and cannot handle any solid particulate matter in their incoming flow that may block or damage the pump. Always refer to manufacturers' guidance on practical limitations of equipment, and protection required.

**Peristaltic pumps** use the principle of an eccentric wheel that revolves to externally massage liquid through a flexible tube, injecting the chemical into water at a rate dependent on the number of rotations and the volume of the flexible tube. The unit requires a flow meter to assess overall water flow to be treated at the point of delivery of the chemical. A computer processor then calculates the frequency of pumping required to achieve a given proportional treatment. Depending on the size of tube and the maximum speed of rotation of the wheel, a greater range of additive concentration can be achieved than for a water-driven dosing pump. The delivery tube becomes worn with repeated use and requires regular maintenance. Peristaltic pumps may be more suitable to very low flow rates, providing a suitable flow meter is used that can measure low flow rates – seeTable 18.

The proportional pumps presently available require either mains or battery supply, which may influence the siting and/or choice of pump. Table 17 includes pumps commonly found on pig units; it should be noted that other systems are also available.

See Appendix 12 for conversion tables for different units, eg psi and bar.
To correctly use each pump, the model should align with:

- The expected pressure of water it is medicating – min, max and range
- The expected flow of water it is medicating
- The proportion of solution it will be expected to inject into the water supply it is treating

A typical system for either pump should contain:

- A water meter to monitor overall water consumption
- A filter upstream of the pump to remove sediment capable of damaging the dosing equipment

- A pressure reducer to protect against surges of high pressure
- Bypass valves to isolate the equipment during periods of non-administration

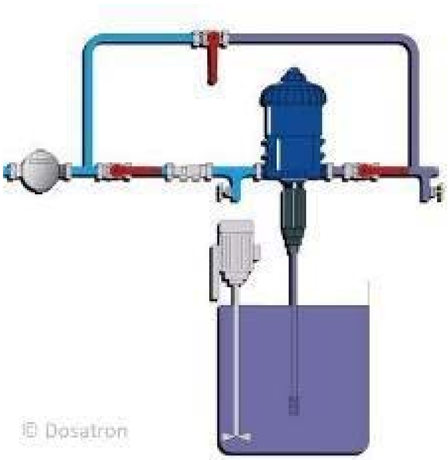




Figure 47. (left) and Figure 48. (right) Proportional dosing systems



Figure 49. (left) and Figure 50. (right) Proportional dosing systems in place on farm

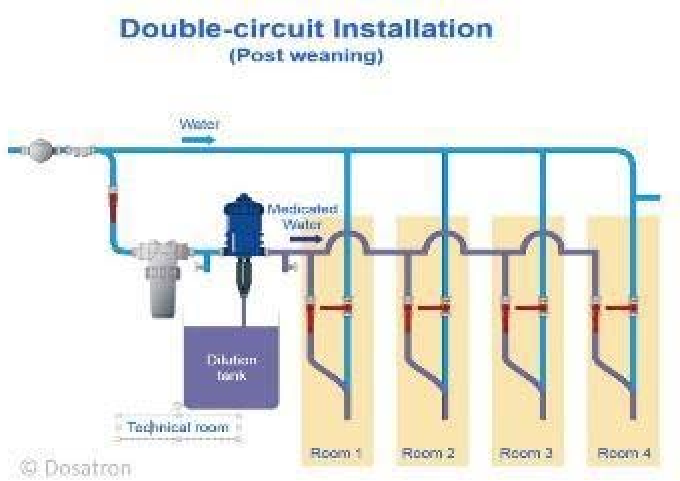



Figure 51. Demonstration of a double-circuit installation post-weaning

**Table 19. Cost benefit analysis of dosing systems**

| | Manual Dosing | Batch Mixing (Header Tank) | Proportional Dosing (Pressure-Driven) | Proportional Dosing (Peristaltic Pumps) |
|---|---|---|---|---|
| **Capital Costs** | None | Low if header tanks already in place | Medium | Medium-high depending on farm specific requirements |
| **Ongoing Costs** | High labour and potentially high wastage | High labour costs and possibly high wastage | Moderate – some maintenance required | Moderate – some maintenance and electricity costs |
| **Accuracy** | Moderate – subject to human error | Moderate – subject to human error | Very good – subject to human error/product longevity | Very good – subject to human error/product longevity |
| **Chemical Handling** | High | High | Low – may require some pre-dilution depending on model used | Very low – can dose straight from drum |
| **Labour Requirement** | High | High | Low – may require some pre-dilution depending on model used | Low – can alter dosing proportions to avoid need for dilution |
| **Flexibility Of Dose Rate** | Wide | Moderate | High – but depends on model and fixed-rate models are more accurate | Very high |

# 8 The use of water as a delivery system for medications

While the quantity and quality of water drunk by pigs is vital to maintain their health and ensure they are able to perform at their biological maximum, drinking water can also serve as a delivery route for both disease prevention and treatment programmes. Administration of medication via water can allow quick and accurate dosing on a large scale, but to do so responsibly requires each farm to have appropriate protocols and equipment to ensure each and every pig receives the correct dose.

**Close cooperation is needed between producers responsible for the welfare and health of their pigs, all relevant staff and the veterinary surgeon designated with the professional responsibility for prescribing medication to them, to ensure responsible medication occurs.**

When administering any medication orally via either food or drinking water, it is obvious that the dose any animal receives must be directly related to their intake of feed or water. Therefore, any situation such as illness that causes intakes to reduce creates a risk of under-dosing sick animals, if estimates of intake are based on the previously normal, healthy intake levels. However, it may be seen that pigs with diseases causing increased body temperatures or inappetence will continue to drink at relatively normal levels even when feed intake is noticeably reduced, so measurement of actual intakes is necessary to properly define suitable inclusion rates of water medicants (personal communication N. Woolfenden, 2016). It is also obvious that some diseases such as those that cause total recumbency or lameness result in animals achieving neither access to feed nor water, and the best treatment system for them would be via the individual injection route.

Compared to the administration of products in feed, which requires the product to navigate sometimes already part-filled feed bins, augers and pen hopper feeders before reaching its target, the administration of products via water can be more precise in terms of the start and end of medication periods, as well as allowing faster administration once the initial decision to medicate is made. With the correct construction of water delivery mechanisms, water medication may also allow more focused administration in terms of the treatment of specific groups or pens of pigs, even if all fed from the same feed line.

Many vaccines that can be administered via water exist within other livestock sectors, but few such vaccines currently exist in pig medicine, with only one product licensed for water administration in the UK in 2017 to date. Where and when vaccines become available for administration via water systems, the risk of under-dosing and the potential implications must be understood.

Water-soluble anthelmintics (‘wormers’) are available under UK licence but the vast majority of medicines currently available for water administration fall into the category of antimicrobials.

**While water-soluble medications such as vitamins and nutritional supplements may be freely purchased, any other product used for treating or preventing disease in animals is legally designated as a Veterinary Medicinal Product (VMP), which may only be prescribed and dispensed by suitably qualified persons, and in the case of antibiotics and vaccines this requires prescription by a registered vet.**

## 8.1 Veterinary Medicinal Product(VMP)

All veterinary surgeons are aware that the use of these products is covered by The Veterinary Medicines (Amendment) Regulations[1, 2], which are updated regularly, with the last issue at time of writing this report (2016) being 2014.

Part of the requirements for issue of a Marketing Authorisation (MA) for a VMP are to make available and keep constantly updated the details of the dosage, indications for use and any possible adverse interactions via a document representing a dossier submitted to either the UK Veterinary Medicines Directorate or the European Medicines Agency that has approved the VMP for use – this is known as the Data Sheet for each VMP. The Summary of Product Characteristics (SPCs) on which the datasheets are based can be found on the VMD website[3] for national registrations or the EMA website[4] for EMA centrally approved products.

Veterinary surgeons are required to prescribe in line with the current SPC, which provides the most up-to-date knowledge on any particular product. The Marketing Authorisation holder must always be the absolute reference point for any information on a specific product.

If there is no suitable veterinary medicine authorised in the UK to treat a particular condition in a particular species, a veterinary surgeon is able to prescribe for an animal under their care in accordance with the prescribing "Cascade"[5].

As part of the Veterinary Medicines Regulations (VMR) (2013), the keeper of any food-producing animals must retain records of the proof of purchase of all medicines bought for an animal. For products administered on farm, but not by a veterinary surgeon, they must also recordthe:

- Name of the product plus batch number
- Date of acquisition
- Quantity acquired
- Name/address of supplier
- Date of administration
- Quantity administered

[1] https://www.gov.uk/guidance/legal-controls-on-veterinary-medicines
[2] http://www.legislation.gov.uk/uksi/2014/599/contents/made
[3] http://www.vmd.defra.gov.uk/ProductionInformationDatabase
[4] www.ema.europa.eu/ema/
[5] https://www.gov.uk/guidance/the-cascade-prescribing-unauthorised-medicines

- Withdrawal period
- ID of animals treated

It is a requirement that these records are kept for at least 5 years, irrespective of whether the animals are sold or die within this period.

The VMR also regulate pharmacovigilance, which monitors any adverse reactions and aims to improve the safety of veterinary medicine products.

### 8.2 Practical considerations when administering veterinary medications via water

Veterinary medicines have to reach the site of their desired action in the body in order to be effective. This therefore requires the prescribing veterinary surgeon to have knowledge of:

- Pharmacokinetics – how the medicine is distributed through the body of the animal
- Pharmacodynamics – how the medicine exerts its desired effect

The specific pharmacokinetic and dynamic properties of all veterinary medicines are included within the MA for the product, allowing veterinary surgeons to seek specific advice on how to use it. For example, some pharmacologically active molecules are relatively insoluble, making their use via water problematic, while others are poorly absorbed from the gastro-intestinal tract and so only able to influence this area directly or have an effect on the microorganisms within it. The importance of understanding product-specific characteristics is therefore evident to achieve the desired effect.

For short-acting, injectable medicines administered as a single bolus/dose, a rapid peak of concentration in blood plasma is produced, which reduces equally rapidly as the body excretes or metabolises the medicine. Water and in-feed medication usually give a lower but flatter plasma concentration curve than an injection or orally administered dose. The intermittent uptake of medicines through the water results in a more constant diffusion of active product from the gut into plasma, and so plasma levels appear more constant than when compared to the administration of a bolus.

In systemic infections, for antimicrobials with a time-dependent effect, the duration of activity is important and continuous medication is necessary to achieve consistent blood levels of the active ingredient. However, for concentration-dependent antimicrobials, the peak concentration achieved in plasma is important for best results, and hence an initial bolus loading dose may be considered. Intentional variation in oral administration to achieve any loading dose required is more easily achieved when administered via the water.

Information on the success or otherwise of mixing different medicines and additives into a single dose was not freely available to the authors at time of writing this report. **Always refer to the manufacturer for advice.**

Figure 52 shows an example of the basic pharmacokinetics of medications administered via different routes. The minimum inhibitory concentration (MIC) is the minimum concentration of antimicrobial needed to have an inhibitory effect on the bacteria. The area under the curve (AUC) but above the MIC depicts duration of activity the antimicrobial can be expected to have an inhibitory effect on the bacteria.

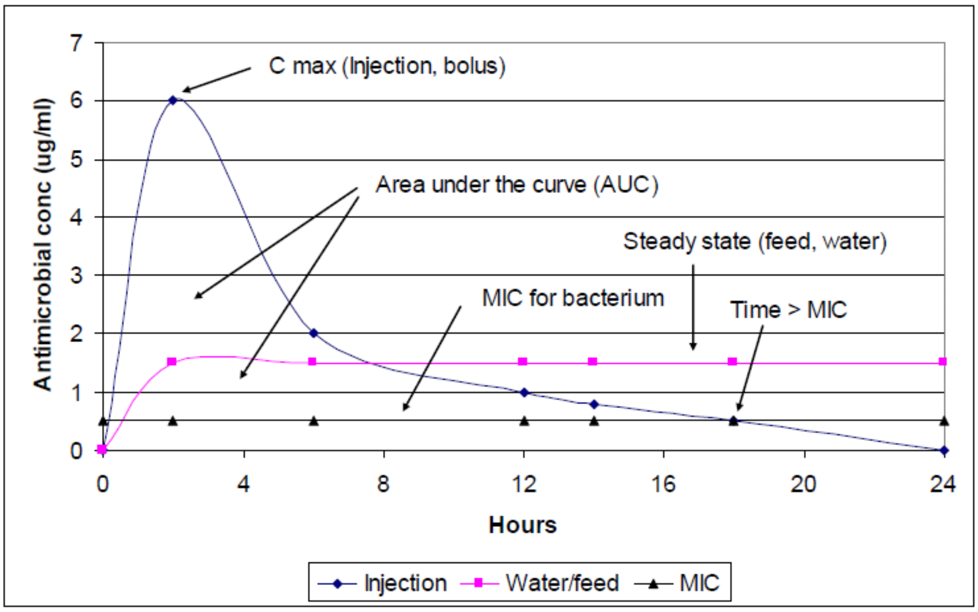



Figure 52. Basic pharmacokinetics of medications administered via different routes

## 8.3 Dose rates

The recommended dose rate is normally based on the concentrations of the product compared to the body weight of the pig being treated – the milligram (mg) of active molecule per kilogram (kg) of body weight dose. In an injectable formulation, the concentration of active ingredient is known and fixed so it is relatively easy to calculate a dose of millilitre (ml) of product per kg of pig. However, to achieve the same with water medication requires the additional step of knowing how much water is actually drunk by a given weight of pig to determine the required concentration strength of the product within the water being administered. A fixed dose of a water-soluble medication in a specific volume of water will rarely lead to the correct daily dose across all categories of pigs.

Although the average daily water requirements for each class of pig are known, it is important to consider the true daily intake depending on diet type and other environmental factors, as well as any possible wastage occurring.

The best guide to expected usage would be to consider the previous measurements of water intake of pigs of the same weight on the same farm. Such data could be made available from previous meter readings of flows if suitable and reliable equipment is available.

The normal diurnal pattern of drinking behaviour in pigs must be considered in terms of the time of commencement of medication to achieve best focus of intake, with the time of peak water intake occurring during the afternoon. Figure 53 shows an example of a typical diurnal drinking pattern.

**Pig health will benefit if producers start to measure and record water flow rates, and use the information to improve water delivery, water quality, and delivery of additives.**

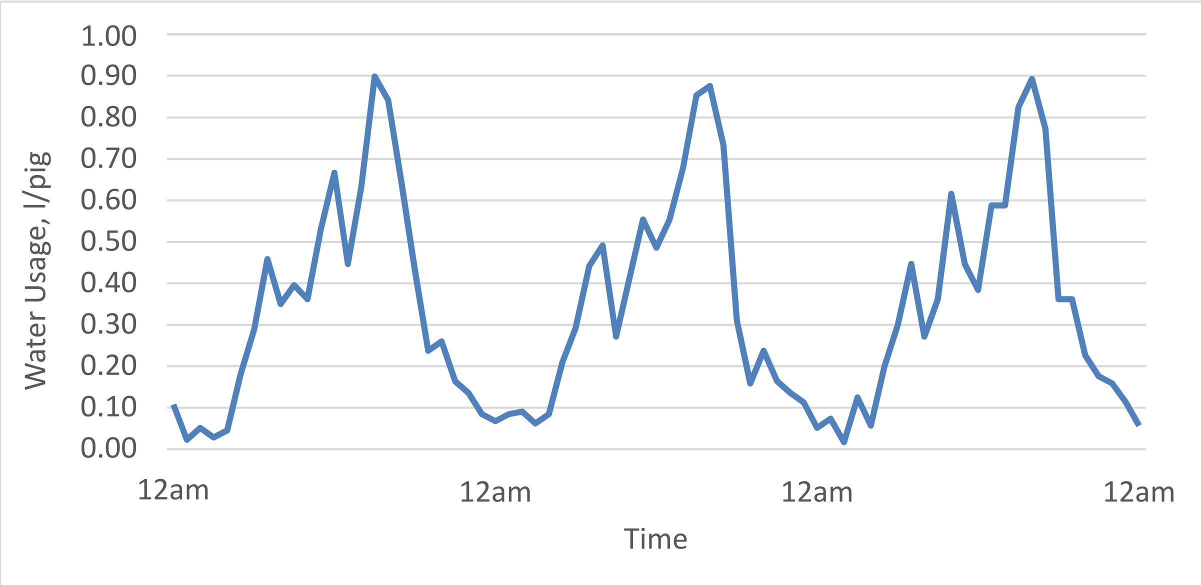



Figure 53. Typical diurnal drinking pattern behaviour displayed by weaned pigs
*Source: Douglas, 2016*

## 8.4 Dose delivery decisions

Water quality must be considered, as some medicines are incompatible with certain dissolved substances commonly found in borehole water. For instance, oxytetracycline and colistin are inactivated by high levels of calcium, magnesium and iron. The range of interactions are many but again, the advice is clear; read the data sheets and discuss any potential issues with knowledgeable people. **If in doubt, contact the manufacturer.**

The presence of biofilm within water systems should also be assessed both before and after administration of veterinary medicinal products and other water-administered compounds such as vitamins. Biofilms will absorb and inactivate some products, including antimicrobials. Pathogenic bacteria in biofilms have been shown to be 1,000 times less susceptible to antimicrobials than the same bacteria free-floating in water. Exposing large numbers of environmental bacteria present in biofilm to antimicrobials does not represent prudent use of these important medications.

Water delivery systems should therefore be clean before administration of any water-soluble medication and also cleaned after their use to remove biofilm that has formed, stimulated by the nutrients present within the administered products.

While sanitisation of water systems before and after medicine administration should occur, simultaneous administration of sanitisers with medicines may render the medicines ineffective. For example, live vaccines cannot be administered concurrent with water disinfection such as chlorination. Manufacturers' data sheets of products should be consulted about the effects of water pH on product effectiveness.

Many products require preparation into a stock solution before delivery into a water system; always check data sheets for maximum solution concentrations to avoid precipitation of product and therefore under dosing.

## 8.5 Best Practices to consider when delivering medicines via water

Considerations of best practice when delivering medicines via water include ensuring that:

- The water system you propose using on farm is fit for purpose, taking guidance from the earlier chapters of this report
- The product specifications have been read thoroughly to ensure the product is stored, handled and formulated correctly
- The product is formulated and delivered in line with the product specifications (eg route of administration, dilution of stock solution)
- The dose is always calculated correctly for the weight of the group of pigs the medication is required for. Several tools are available to assist with this to avoid errors. Calculating the dose incorrectly can have potentially catastrophic effects depending on the product
- The stock solution is formulated to the correct concentration and completely suspended. The use of mixing equipment including magnetic stirrers should be considered to ensure the solution is completely and consistently mixed throughout the solution
- The stock solution is stored in line with the product's specific requirements (eg in a clean environment, free from contamination, made up at regular intervals)

**If in doubt, always seek professional advice.**

## 8.6 Consideration when treating infections in pigs with water-soluble antimicrobials

In the main, soluble products given via drinking water pass rapidly through the stomach and are quickly absorbed compared to the same molecules administered via feed, making water delivery effective for systemic or blood-borne infections. However, some products given orally are hardly absorbed from the gut, such as the aminoglycosides (eg neomycin, apramycin) or aminocyclitols (eg spectinomycin), making them of little use for systematic or respiratory infections. The rapid absorption of water-soluble compounds makes some formulations of the same molecule more bio-available and thus able to achieve higher lung concentration than when administered in feed, (eg tiamulin). Note that this more complete absorption in the gut can make it more difficult to achieve effective concentrations in the hind gut, caecum and colon, if needed. Understanding the product characteristics (eg route of administration, dose rate, etc.) is vital to ensure maximal effect is seen. The product licence or SPC should be referred to in any doubt.

Example of how to utilise a proportional pump to administer a stock solution of time-dependent medication:

1. Determine the daily dose of the product in terms of mg of product/kg of pig treated eg 20mg/kg of pig

| |
|---|
| It is important that pigs are dosed as accurately as possible. Determining their true body weight is key to this. The use of electronic weigh scales would be recommended to ensure the correct weights are used to calculate doses. |

2. Use the number of pigs in the population and their average weight to calculate the total weight of pig to be treated eg 300 pigs at an average 20kg weight = 6,000kg
3. Calculate the total daily dose required to be administered, eg 20mg/kg times 6,000kg = 120,000mg or 120g of product
4. Measure the average daily water intake or calculate based on 7–10 per cent intake, eg 20kg pig drinks 2/day so total daily intake equals 600l
5. Know or set the proportion of the pump, eg 2 per cent
6. Make up the stock solution using 2 per cent of 600l = 12l and add 120g of product (from step 3). Consult the product SPC or contact the manufacturer for advice on the most appropriate water temperature to use to ensure the product completely dissolves. It would be best to mix in a clean white bucket to see that good mixing occurs. Stirring is often required to improve dissolution. Cover the solution to avoid contamination and exposure to strong sunlight. Stock solutions should not be made up with water treated with common water disinfectants, except with manufacturer's agreement
7. Connect the pump to the waterline and administer the product over 24 hours. Ensure the stock solution is being depleted as expected and stays adequately mixed. An electric stirrer may be required. Mix up fresh product each day or more frequently according to manufacturer's instructions
8. Beware product does not settle out of solution in cold weather or that the solubility of the product in the stock solution is not exceeded
9. Record all medicines usage and observe the necessary withdrawal time before marketing the treated animals

10. Clean down the water line and pump with a suitable product at a concentration that would allow pigs to consume the water. This will avoid residue and biofilm build-up in pipes and drinkers, as well as lower risk of antimicrobial resistance developing.

When administering a dose-dependent product, the same principles apply, with the exception of Point 7. These products rely for their effect on the maximal correct concentration of the product being delivered to the animal, and so the duration over which these products are administered is less relevant. Instead, it is advised that these products are administered over periods of highest water intake to ensure the correct response is achieved.

## Conclusion

The provision of a plentiful and clean water supply is paramount to ensure the efficiency of production from farrowing through growth and finishing, and vitally around the time of lactation for sows. Ensuring the mineral, microbiological and chemical components of the water source are correct is key to prevent any adverse effects to the health and production of the pigs. Alongside this however, it is paramount to ensure that correct type and number of drinkers are selected for each group of pigs and that their placement within the pen is carefully thought out to make sure the pigs receive the expected volume of water.

Maintaining a clean water delivery system is key to making sure the benefits of clean and plentiful water continue to be seen. Routine testing and cleaning procedures may be required to achieve this. The cost benefit of managing and sustaining a clean water supply is a predictable and stable baseline of health, and has the potential to further reduce antibiotic requirements. Having a clean and fully functioning water delivery system is also important if it is to be used for the delivery of in-water medications (including antimicrobials, vaccines and anti-parasitics). Without the knowledge that the pigs will receive the calculated volume of clean water, it is impossible to ensure they will receive the correct, therapeutic dose of any medication delivered through the water. Clean water delivery is good practice and good business.

## Appendix 1 Water standards for pig production for dissolved minerals in other countries, compared with human EPA* standards

| | **Dutch Standards** | | Canadian Standards | USA Standards | EPA* Standards (human) |
|---|---|---|---|---|---|
| | **No Risk (ppm)** | **Risk (ppm)** | Maximum concentration (ppm) | Maximum Concentration (ppm) | Maximum concentration (ppm) |
| **pH** | **5–8** | **>9 and <4** | n/a | n/a | 6.5–8.5 |
| **Ammonia1** | **<1** | **>2** | n/a | n/a | n/a |
| **Nitrite (as N)** | **<0.1** | **>1** | 10 | 10 | 1 |
| **Nitrate (as N)** | **<25** | **>100** | 100 | 100 | 10 |
| **Chloride** | **<250** | **>1,000** | n/a | n/a | 250 |
| **Salt (via NA)** | **<1,000** | **>2,000** | n/a | 3,000 | n/a |
| **Iron** | **<0.2** | **n/a** | n/a | n/a | 0.3 |
| **Manganese** | **<1** | **>2** | n/a | n/a | 0.05 |
| **Sulphate** | **<100** | **>250** | 1,000 | n/a | 500 |
| **Calcium** | n/a | n/a | 1,000 | n/a | n/a |
| **TDS** | n/a | n/a | 3000 | n/a | 500 |
| **Aluminium** | n/a | n/a | 5 | 5 | n/a |
| **Arsenic** | n/a | n/a | 0.03 | 0.2 | n/a |
| **Beryllium** | n/a | n/a | 0.10 | n/a | n/a |
| **Boron** | n/a | n/a | 5 | 5 | n/a |
| **Cadmium** | n/a | n/a | 0.08 | 50 | n/a |
| **Chromium** | n/a | n/a | 0.05 | 1 | n/a |
| **Cobalt** | n/a | n/a | 1 | 1 | n/a |
| **Fluoride** | n/a | n/a | n/a | 2 | n/a |
| **Lead** | n/a | n/a | 0.10 | 0.05–1 | n/a |
| **Mercury** | n/a | n/a | 0.003 | 0.01 | n/a |
| **Molybdenum** | n/a | n/a | 0.50 | n/a | n/a |
| **Nickel** | n/a | n/a | 1 | n/a | n/a |
| **Phenols** | n/a | n/a | 0.002 | n/a | n/a |
| **Selenium** | n/a | n/a | 0.05 | 0.5 | n/a |
| **Vanadium** | | | 0.1 | | |
| **Zinc** | n/a | n/a | 50 | 25 | n/a |

**Source: Dutch, Canadian, USA and US Environmental Protection Agency (EPA) water quality recommended guidelines*

**It is recommended that the Dutch standards are used as reference for water quality parameters**. If a borehole drain from sand/gravel is less than 20m deep or able to be contaminated by surface later, then it is recommended to sample **twice per year as a minimum** – preferably once at low rainfall and once after heavy rainfall.

## Appendix 2 Suggested water standards for pig production ~ biological screen

The **recommended** reference levels for microbial screening of water used in pig production can be found below.

| Microbiological Measure | Acceptable level (CFU) |
|---|---|
| TVC (at 22°C) | <1,000 per ml* |
| TVC (at 37°C) | <1,000 per ml* |
| Total coliforms | <100 per 100ml* |
| *E. coli* | None detected in 100ml |

**Source: Red Tractor Farm Assurance Pigs Standard, 2017*

If a borehole drain from sand/gravel is less than 20m deep or able to be contaminated by surface water, then it is recommended to sample **twice per year as a minimum** – preferably once at low rainfall and once after heavy rainfall.

**Although accredited laboratories are available, it is recommended that the frequency of testing be upheld with a non-accredited laboratory if cost is considered as a barrier to testing.**

It would be recommended to speak to your local AHDB Pork representative, who should be able to help suggest an appropriate laboratory to use.

# Appendix 3 Water sampling for bacteriology analysis

**Equipment List**

- **Sterile** sample bottles containing chlorine neutraliser chemicals are needed for bacteriology analysis
- Usually a minimum of 500ml is required but consult the laboratory first
- Disposable gloves
- Marker pen
- Labels
- Insulated container suitable for transport (such as a polystyrene box)
- Submission form for laboratory

**Key Points**

- Check the sterility seal on the bacteriology sample bottle is unbroken
- Keep the sample bottle unopened until just before it is filled

**TAKE CARE NOT TO SPILL OR TIP OUT THE PRESERVATIVE WITHIN THE MICROBIOLOGY SAMPLING BOTTLE.**

- Do not touch inside the mouth of the bottle at any point
- Do not rinse out a bottle before taking a sample

**Sampling points**

Each farm may require samples from multiple sampling points. The sampling points should each be labelled with the sampling position and date, as well as the farm name.

1. **Point of entry** (this is the point at which the water comes onto the farm, as close to the boundary/borehole/tee of mains as possible). This is the best point for mineral analysis sampling, and a bacteriology sample should also be taken here
2. Immediate **post-weaning, farrowing and dry sow accommodation** are more likely to be affected by poor water quality so consider these for sampling
3. **Far end of the water line**: This is the furthest point of the furthest spur from where the water enters the farm chosen to indicate the quality of water, after it has passed through the maximum length of farm plumbing
4. As drinkers and troughs in occupied pens are often contaminated from the mouths of pigs, it may be best to sample from **cleaned but not disinfected drinkers** in empty pens or from the top of the drop-pipe supplying the furthest drinker in occupied pens

**Sample Procedure**

1. Label each bottle with site of sampling before starting
2. Put on clean, disposable gloves before handling the sample bottle
3. Keep the sample bottle unopened until just before it is filled. Do not touch inside the mouth of the bottle at any point
4. Open the sampling point and let water flow for 30 seconds
5. Open the bottle - retain the cap but do not touch inside it
   **Do not empty any preservative from the bottle!**
6. Fill the bottle from a gentle stream **directly from the sampling point** without touching the bottle onto any pipe or surface and without overfilling (fill to within 2cm from the lid)
7. Screw the cap on tightly
8. Gently invert the bottle 3 times
9. Arrange delivery to the laboratory. It is important that the laboratory receives the sample(s) **within 24 hours of it being taken**
   While the sample is awaiting collection by postage/courier, chill the bottle to normal fridge temperature if possible. Do not freeze. Ideally, send the sample to the laboratory in an insulated box with ice bricks to maintain a temperature, if available
10. Reassemble waterline/drinker components and check water delivery at drinkers

The **frequency** of sampling is key to allow a thorough and complete understanding of the mineral and microbiological make-up of the water in your system. Although accredited laboratories are available, use of these laboratories should not be the barrier to the frequency of testing, if a more cost-effective means of testing can be established.

## Appendix 4 Considerations When Designing a Farm Water Supply System for Pig Accommodation

*Source: AHDB Pork, 2016*

**Introduction**

AHDB Pork has commissioned Reading Agricultural Consultants (RAC) to produce a proposal setting out a case study of considerations when planning a farm water supply system for pig accommodation. The case study considers a wide range of issues relating to good infrastructure and hygienic water supply for pigs and cleaning water systems, and the planned inclusion of medication in the drinking water.

This document sets out the principal issues when looking at the renovation and installation of water supply systems on farms and the design of distribution and drinking systems, including standard values and calculations to ensure that water is distributed safely around the farm at flow rates and pressures that deliver volumes that satisfy the demand from livestock.

> When designing a new water supply system it is advised that you consult a competent livestock plumber.

In addition to the report below, the following example design calculation for a simple plumbing system helps to demonstrate the requirements of setting up and maintaining an effective infrastructure that is conducive to clean water delivery;

**Example calculation:**

Building specification:

- 1040 place traditional finisher building with slatted floor
- Building dimensions approx. 61.3m x 12.5m
- 40 pens: 20 pens per side each with 26 pigs per pen up to slaughter weight of 105-110kg (dimensions: 3.0m x 5.6m)
- Nipple drinkers per pen, ad lib dry feeding system

Advised water supply system requirements:
The building will need 80 drinkers in total with a supply of 1.0-1.5l/min; this can be achieved with a standard drinker with a 1mm orifice plate, working at 1.2l/min @ 2bar. 2bar operating pressure is 20 metres head.

This is a total flow of 96l/min – 1.6l/sec.

At such a high flow, if fed from one end, you would need a 50mm supply pipe and an input pressure of 3.1bar. That is 31m head – this cannot be achieved with a header tank, and a booster pump and pressure set may need to be considered.

The specification can be reduced with a centre feed, which would have to be 50mm, but the lines along the house could be 40mm, with an operating pressure of 2.5bar (25.5m head). Likewise, multiple header tanks per building will reduce the specification.

**Water supply regulations**

Farmers, like all others served by a public water supply, must comply with the Water Supply Regulations[1]. By following the requirements of these regulations, farmers protect the water supply from contamination, both on the farm and, critically, in the system prior to the farm (upstream). Furthermore, the Regulations are designed to prevent the waste of water (avoiding a waste of money where supplies are metered) and to ensure they have reliable and robust plumbing systems that will give good service.

Compliance with the Water Supply Regulations is enforced by the water supply companies, which subscribe to the Water Regulations Advisory Service (WRAS). This body approves plumbing pipes and fittings for use in connection to the public water supply. The term WRAS has become 'shorthand' in the UK for covering three separate areas.

The first is the WRAS company itself, which is a subscription membership company. The subscribers of WRAS are the 26 UK water suppliers[2]. The second is used as shorthand for 'meeting the Water Regulations of 1999' (which is not in fact the case). The third is used for approved plumbing fittings.

It is *not* illegal to install a product such as water fittings in the UK without the WRAS mark, but you may have to prove compliance in other ways.

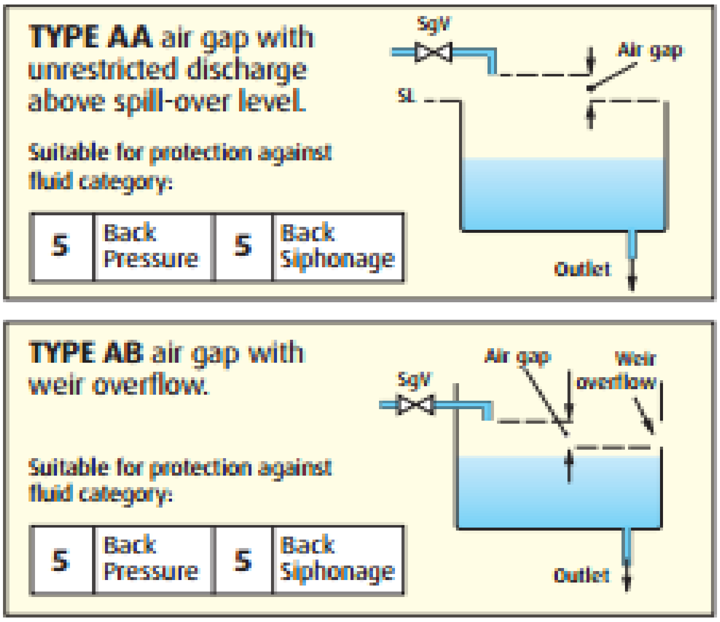
**Preventing contamination of incoming mains water supplies**

Livestock farm water supplies fall within the highest risk category, as faecal matter or chemicals entering the system have potential to cause significant harm. They are rated as Category 5 installations, which is the highest risk group.

Water supplies to livestock accommodation and yard areas have to be protected by an air gap to prevent the back-flow of potentially contaminated or medicated water into the public supply. All pipes and fittings before the air gap have to meet the standards set by the regulations. It is recommended that pipes and fittings after the air gap be approved by WRAS; it is in the farm's business interest that fittings do not leak or contaminate the supply.

[1] Water Supply (Water Fittings) Regulations 1999, the Scottish Water Byelaws 2004 and the Water Supply (Water Fittings) Regulations (Northern Ireland) 2009.

[2] https://en.wikipedia.org/wiki/Water_Regulations_Advisory_Scheme#cite_note-1




Source: Water Regulations Advisory Scheme

Figure 1: Header tank air gap arrangements for Category 5 installations.

Figure 1 shows how an air gap should be created to protect the public water supply from risk of contamination with medicines, faecal material or pathogens. In order to meet these regulations, trough and bowl drinkers have the float valve sitting in a header box above the top of the sides.

Note: The vertical distance of the discharge point of inlet pipe above spill-over level must be at least twice the bore of inlet pipe and never less than 20mm.

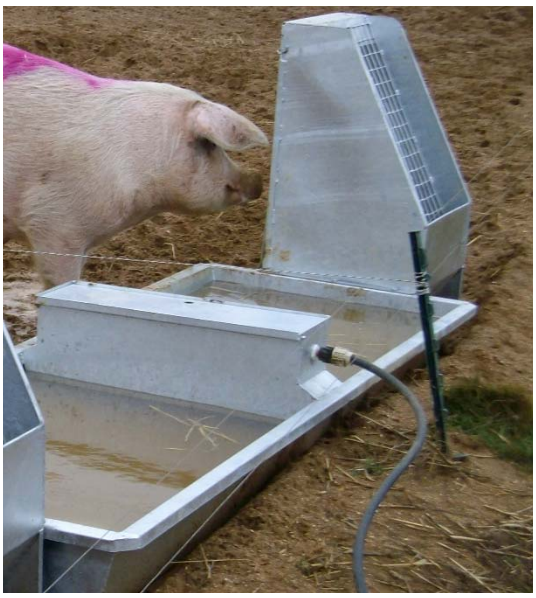


Photo 1: Water trough with valve box above sides to eliminate back-flow.

# 1 Source of Supply

If you use the public water supply from the water company-owned distribution mains, it is reasonable to assume that the supply at the meter is potable and free from contamination. However, treatment may include chlorination and sometimes fluoridation, which may have an impact on herd health.

Private water supplies from boreholes, springs or surface water are less reliable in terms of microbial and chemical quality. They may require treatment before storage to bring the water up to a standard suitable for pigs. Treatment may include ultraviolet light (UV) for microbial contamination, and chemical dosing or filtration to remove iron, suspended solids or other contaminants.

On-farm supplies should be protected from contamination by implementing precautions set out in the Code of Good Agricultural Practice (COGAP) for the protection of soil, water and air. Manures and slurries should not be stored on, or applied to, land within 50 m of a borehole used for private water supplies, and such boreholes should not be located within 50 m of a soakaway attached to a domestic septic tank system, sprayer wash-down pad, blind ditch soakaway or biobed. In some limestone and sandstone aquifers, greater protection may be necessary to protect supplies against microbial contamination.

# 2 Treatment of Main Supply

Where the water quality is poor or the supply is at risk of contamination, testing should be carried out to determine the nature and degree of treatment necessary to bring the supply up to potable standard.

Basic testing of private supplies should be undertaken regularly, with samples taken from the primary outlet from the source to storage, or in the case of pressurised borehole-fed systems, from an outlet at the head of the borehole. Testing should be carried out for the following parameters directly related to a healthy supply: lead, copper, nickel, *Escherichia coli (E. coli*) and *Enterococci.* The flowing parameters also should be tested for general quality and to assess potential impacts of the water on the distribution system: smell, taste, biological oxygen demand, hardness, suspended solids, conductivity (salinity) and iron.

Treatment systems should be capable of handling the full rate of flow of the farm supply and the water placed in suitable storage to provide a buffer against breakdown and other breaks in supply.

# 3 On-Site Storage

Primary storage should be protected against contamination and freezing, and should be in a lined steel (galvanised, enamelled or plastic), stainless steel or polyethylene tank with access for cleaning. The stored water should be protected from access by vermin and insects in the same way as domestic supplies. The inlet to the tank should be fitted with a control to prevent overflow, such as a ball valve, and an overflow pipe installed to ensure at least 20mm freeboard, twice the diameter of the supply pipe, between the inlet and maximum level of stored water (Figure 1). Secondary storage may be provided at individual accommodation areas. All such storage should be installed to the same standard as the primary storage facility.

The volume of on-site storage should provide a buffer for use in the event of a break in water supply resulting from power outage, mechanical breakdown, or a break in supply from the mains. In the case of water mains-supplied sites, your water provider should be notified of the presence of a livestock unit and the scale of demand on an hourly and daily basis.

There are no recommendations for the scale of any emergency supply, but the average daily consumption across a site can be estimated from the following table from the Code of Recommendations for the Welfare of Pigs (‘Pig Welfare Code’).

Table 1: Daily Water Requirements and Minimum Flow Rates

| Weight of pigs (kg) | Minimum daily requirement (l/head) | Minimum flow through nipple drinker (l/min) |
|---|---|---|
| Newly weaned | 1.0 – 1.5 | 0.3 |
| Up to 20 kg | 1.5 – 2.0 | 0.5 – 1.0 |
| 20–40 kg | 2.0 – 5.0 | 1.0 – 1.5 |
| Finishing pigs up to 100 kg | 5.0 – 6.0 | 1.0 – 1.5 |
| Sows and gilts pre-service and in-pig | 5.0 – 8.0 | 2.0 |
| Sows and gilts in lactation | 15 – 30 | 2.0 |
| Boars | 5.0 – 8.0 | 2.0 |

Source: Paragraph 72 of the Pig Welfare Code

Careful consideration should be given to the risks to pig welfare associated with any disruption in the water supply and the availability of alternative supplies in terms of available volumes and speed of response.

# 4 Pumping and Distribution

**Pump systems**

Pumping systems can be divided into source: primary and secondary. Primary pumping systems distribute water around the site to zones of use, which may differ in terms of pressure, water quality or added medicines. Primary systems could be used for direct supply of washing water at a relatively high flow and low pressure, and to supply to secondary storage or pressure-boosted supply systems. Systems should be closed and fitted with pressure vessels to reduce pump stop/starts and metering to gauge use and detect possible losses through leaks. Secondary systems should also be metered and fitted with pressure regulators to ensure the systems are not over pressurised and to monitor water use and aid leakage detection.

Pumping and distribution systems should also be protected from freezing using insulation and thermostat-triggered trace or space heating where the plant is in an uninsulated building. Pumps should be standardised as much as possible to ease replacement and routine servicing. The use of duty and standby primary pumps should be considered. Pump systems should be fitted with breakdown alarms to reduce the risk of supply failure.

The water supply system design must account for pressure (friction) loss in pipes. Pressure loss is the reduction in pressure or ‘head’ along a pipeline due to the viscosity near the surface of the pipe.

One bar pressure is equivalent to about 10 metres head.

The lowest pressure at which many types of nipple drinkers will work is 0.2 bar.

For these drinkers, if the header tank is less than 2m (6 feet) above the level of the drinkers, it will not work.

Some nipple drinkers need between 1 and 2 bar pressure to work properly. For these a pumped system is likely needed as any header tank will need to be 10–20m (30–60 feet) high.

**Pipe diameter and water velocity**

Water velocity, meaning the speed at which water travels along a pipe, is critical to avoid excessively high friction losses and to prevent water hammer.

Distribution mains should be specified to ensure a maximum water velocity of:

- 1.25m/sec in 25–63mm pipe
- 2.00m/sec in pipes greater than 90mm diameter.

This is important to reduce the risk of damage caused by water hammer and to keep friction losses at an acceptable level.

Designers use head loss charts or simple computer programs available from pipe suppliers to establish friction loss. The liquid creates friction loss, e.g. water dragging on the pipe surface. A rough steel pipe wall creates more friction than a smooth MDPE pipe. An example nomogram for PE and uPVC pipes is attached at the end of this document (figure 5) and has been used in our example calculations.

Within a building, laterals supplying nipple drinkers and troughs should be specified with a friction loss of less than 20% of the average operating pressure of the nipple drinkers or troughs with all outlets open. This ensures there is no more than 10% variation in the water supplied at the outlets. In accommodation with more than one supply line, consideration should be given to the creation of ring distribution systems that equalise flow around the house and reduce friction losses.

Isolation valves should be installed at all tanks or pump inlets and outlets to enable plant and fittings to be maintained without draining down whole areas of distribution systems. For mains water systems, water byelaws also require service valves upstream of float valves and the ability to isolate each individual building on the supply network.

It is important to ensure that all animals always have access to the right amounts of drinking water.

This is done by keeping pressure loss in any section of pipework (lateral or header main) to less than 20% of the average operating (or outlet) pressure along each pipe run in every command area.

The detailed design and specification of main pumping and distribution systems should be carried out after deciding on the design of drinking systems for individual pig buildings. This information will give pressure and flow needs at points around the site.

# 5 Treatment within the Farm

The addition of medicines will be achieved by the use of a calibrated dosing system that injects measured volumes of medicines or other chemicals. This system will be installed in the main input line to stocking areas. Many dosing systems for medicines can also deliver cleaning chemicals at accurate rates.

Photos 2 and 3: Portable dosing set-up

To function effectively, it is important to match the injector size to peak demand by livestock. It is also particularly important to ensure the correct medicines are delivered at the correct doses.

Dosing systems should have a secure means of adjustment, accessed by key or electronic code. The washer disinfector should be fitted with an alarm to indicate when there is insufficient medicine or chemical available.

Dosing systems should be subjected to regular (at least weekly) cleaning, inspection and maintenance, and periodic (annual) calibration. Testing should include:

- visual inspection of pipework to ensure there are no leaks;
- visual inspection/testing to ensure pipework is not blocked by additives;
- cleaning or replacement of pipework as necessary;
- visual inspection and maintenance of pinch tubing on peristaltic pumps or dosing pistons in line with the manufacturer's instructions; and
- checking there is sufficient additive available and that it is dosed.

A veterinarian or a suitably qualified engineer should periodically check the calibration.

Photo 4: Portable dosing set-up

# 6 Demand

Ready access to fresh water underpins the first of the five freedoms set out in the Pig Welfare Code. It also sets out daily water requirements for pigs at all stages of production, together with minimum flow rates and trough space per animal. The Pig Welfare Code recommends that when *ad lib* feeding each nipple drinker should provide an adequate flow for 15 pigs and on rationed feeding for 10 pigs.

In rationed feeding regimes, it is important to ensure that water is available at the right flow rate to reduce avoidable delays at drinkers. It also avoids fighting, as animals that have recently eaten look for water.

Strictly speaking, peak demand in any building is when all drinkers are used simultaneously. However, in many installations there are significant differences in pressure and flow between the first and last drinkers in buildings during periods of maximum demand. It is particularly important to avoid this in rationed feeding regimes.

# 7 Design of a Water Distribution System

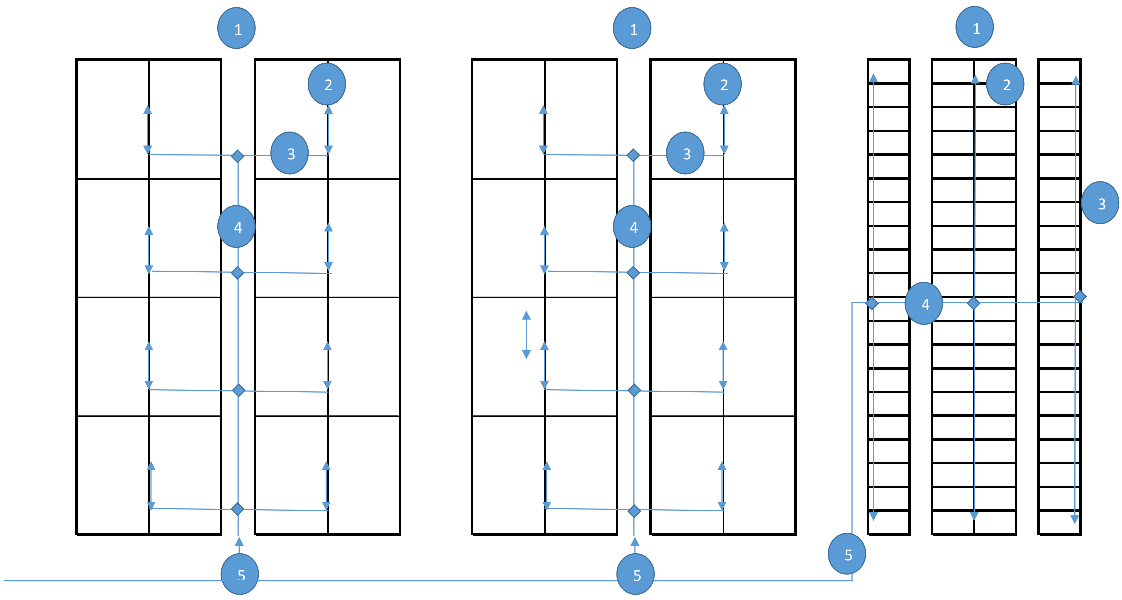
When designing and specifying a watering system, farms should be divided into 'command areas', which may comprise one or more buildings or differently stocked areas in a single building. To minimise pressure differences between drinking points, the pipelines in command areas should be divided into 'header mains' and 'laterals'.

For instance, groups of buildings of similar age and design, or used for a common purpose, such as farrowing, weaning, rearing or finishing, might form a command area as water demands are likely to be uniform across the group.

The following details how to determine pipe diameters and flow rates needed to distribute water around a farm.

The example is based on three buildings in layout 1 (two dry sow and one farrowing), which can be split into two command areas with common characteristics and common design features. [1]
Within the command areas, the design of the supply system is first driven by the number, size and supply requirements of drinkers. [2]
This in turn determines the diameter of laterals. [3]
These then determine the diameter of the main supply lines [4] and ultimately the pressure at the inlet to the system. [5]

Figure 2: Layout 1 – Groups of buildings




| Most routine tests of water supply in pig housing measure flow only at one outlet and do not consider groups of drinkers in a building being used at the same time. Such tests are <u>not reliable indicators</u> of flow rates across a building or even within a single pen. |
|---|

**Step by step system design**

The following sequence should be used when designing a new water supply system for a pig unit.

1. **Identify Water Supply Command Areas:** [1]

   Individual buildings or closely grouped buildings, like those housing the same age of pigs, will have similar flow and pressure needs at the point of supply, which may be at one end or in the centre of each building.

2. **Identify Demand:** [2]

   Estimate the number and type of drinkers needed to supply groups of pigs within the buildings.

   *<u>Nipple drinkers or bowls</u>*

   Whether nipple or bowl drinkers, a drinking point should be available for the following numbers of pigs rationed and *ad lib* feeding (Table 2).

Table 2: Drinking point requirements based on drinker type

| Drinker Type | Minimum Number Grower/Finisher Pigs |
|---|---|

| | |
|---|---|
| Nipple Drinker (restricted feeding) | 1 per 10 pigs |
| Nipple Drinker (*ad lib* feeding) | 1 per 15 pigs |
| Bowl (restricted feeding) | 1 per 20 pigs |
| Bowl (*ad lib* feeding) | 1 per 30 pigs |

Source: Paragraph 75 of the Pig Welfare Code

The minimum flow rate through drinkers for pig groups is shown in Table 3.

Table 3: Minimum flow rate through drinkers for pig groups

| **Weight of pigs (kg)** | **Minimum flow through nipple drinker (l/min)** |
|---|---|
| Newly weaned | 0.3 |
| Up to 20kg | 0.5 – 1.0 |
| 20–40kg | 1.0 – 1.5 |
| Finishing pigs up to 100kg | 1.0 – 1.5 |
| Sows and gilts pre-service and in-pig | 2.0 |
| Sows and gilts in lactation | 2.0 |
| Boars | 2.0 |

Source: Paragraph 72 of the Pig Welfare Code

***Example***: A group of 60 *ad lib*-fed growing pigs will require four nipple drinkers, each with a flow rate of between 1.0 and 1.5l/min, for a total of 4–6l/min/group.
A building housing eight such groups will require a supply of between 32 and 48l/min. That is between 7 and 10 gallons/min.

*Troughs*
Where trough systems are used, the guidelines outlined in Table 4 should be applied.

Table 4: Trough and bowl Space

| **Pig Weight (kg)** | **Trough Space per Head (cm)** |
|---|---|
| Up to 15 | 0.8 |
| 15 – 35 | 1.0 |
| Over 35 | 1.2 |
| | Bowl |
| Restricted Feeding | 1 per 20 pigs |
| *Ad Lib* Feeding | 1 per 30 pigs |

Source: Paragraph 75 of Pig Welfare Code

***Example***: A group of 60 *ad lib* fed growing pigs would require a minimum trough length of 72 cm (60 x 1.2 cm), or two bowls.

Because troughs and bowls provide a buffer supply of water, the flow rate at the ball valve can be 50% of an equivalent group of nipple drinkers.

Thus, a group of 60 pigs would need a flow rate of 2–3l/min. A building housing eight such groups will require a supply of between **16 and 24l/min. That is between 3.5 and 5 gallons/min.**

### 3. Specify Drinkers and Laterals for Groups

Detailing drinkers to establish maximum lateral friction loss.

Having identified the required flow rate required to supply the number of drinkers required, the drinkers can be detailed.

The size of a nipple drinker is determined by the type of pig it is intended to serve. Water pressure influences flow rate; therefore, manufacturers often supply a means to restrict flow so that the correct flow rate can be delivered given the pressure available *in situ*. This adjustment is often enabled by the use of plastic inserts with a set orifice diameter, where the colours differentiate between orifice diameters. Other types require the disc to be rotated.

Table 5 shows the pressure–flow relationship for a nipple drinker that can be fitted with inserts of different orifice diameters.

Table 5: Flow Rates (l/min) of nipple drinkers

| **Flow L/min** | **Pressure (bar)** | | | | |
|---|---|---|---|---|---|
| **Orifice (mm)** | 0.2 | 1 | 2 | 3 | 4 |
| 0.8 | 0.15 | 0.34 | 0.48 | 0.65 | 0.88 |
| 1.0 | 0.35 | **0.8** | **1.20** | **1.72** | **2.30** |
| 2.0 | **1.31** | **2.10** | 2.80 | 3.70 | 4.30 |

Note: the colour coding relates to the example below

***Example: selecting the correct insert for a nipple drinker***

**1)** Selecting drinkers for growing pigs (Table 3; 20–100kg):

A header tank producing 0.2 bar will provide a flow rate of **1.31**l/min when the nipple is fitted with a 2.0 mm diameter orifice insert.

Alternatively, an orifice of 1.0 mm at 2 bar pressure delivers a flow of **1.2**l/min, or slightly over-deliver at a pressure of 3 bar and 3 mm orifice, **1.72**l/min.

The lateral supplying a group of drinkers should be specified to have a friction loss of less than 20% of the operating pressure of the nipples.

Therefore, in this example, the friction loss in the lateral should not exceed:
0.04 bar (0.4m pressure head), thus a header tank will need to be at least 2.4m above the drinker

0.4 bar, where 2 bar delivery pressure is required
and
0.6 bar where 3 bar delivery pressure is required.

**2) Selecting drinkers for sows and gilts**

Using Table 3, an orifice of 2.0mm at 1 bar pressure delivers a flow of 2.1l/min, which suits the need of sows and gilts at all stages, as well as boars.

The lateral supplying a group of drinkers should be specified to have a friction loss of less than 20% of the operating pressure of the nipples, that is 0.2 bar or about 2m pressure.

Alternatively, if a 1.0mm diameter orifice insert was selected, the system would need to deliver a much higher 4 bar.

Determining pipe diameter of laterals 3

In cases where the feeder lateral is 25mm in diameter and there are six or fewer outlets delivering a total of less than 12l/min, the friction loss between drinkers on lateral feeds to individual pens will not exceed 20% of the operating pressure. It is reasonable to assume that a lateral inlet pressure equal to the required nipple pressure will be adequate.

Therefore, in the case of a header tank supply, a lateral feeding four nipple drinkers with a 2.0mm orifice insert will require a flow-rate of 5.24l/min (Table 5; 4 x 1.31 = 5.24)

Alternatively, if the supply pressure is 2 bar, the required flow rate is 4.8l/min with a 1.0 mm diameter orifice insert (Table 5 4 x 1.2 = 4.8).

In the case of example 2 above, where the supply is for sow accommodation, the pressure–flow specification for supply laterals to feed four 2.0 mm orifice drinkers is a flow of 11.2l/min at a minimum of 2 bar pressure at the inlet from the header main.

**REMEMBER: Keep pressure loss in lateral to less than 20% of line operating pressure to ensure that all animals can always get the right amount of drinking water.**

## 4. Specify Water Supply Header Mains Pipe Diameter 4

The pipe diameter and operating pressure of the header main supplying the ends of drinker laterals must be sized to avoid drinkers at the end of the line suffering reduced pressure and so failing to provide sufficient water to stock. Again, the friction loss between the first and last lateral on the header main should not exceed 20% of the operating pressure. Losses in supply mains are calculated using the attached nomogram (figure 5).

The layout of header mains in relation to drinking areas should be designed carefully. Generally, in buildings containing a small number of large pens, a single central header main of 32 mm or greater used to distribute to single or pairs of drinker laterals can save pipeline costs (see fig 2 at start of the section). Offtakes from the header main can be either end tees or single or double saddles with 1" threaded outlets; double saddles can save fittings costs over single feeder mains and tees used to service one row of pens.

T piece  Single saddle  Double saddle 

Source: Images courtesy of Plasson UK Ltd

In buildings like farrowing houses, where individual drinkers are distributed evenly along the length of the building, consideration should be given to one or more feeds into the laterals at or near the centre of the building (see plan at start of section). Make sure that friction losses in the pipe run do not exceed 20% of the operating pressure, particularly where a single lateral feeds two rows of pens.

All calculations so far have been in l/min flow and bar pressure. Losses in pipelines are normally worked out in l/sec and bar or metres of head pressure. Thus it is necessary to convert flow rates to l/sec.

| |
|---|
| 1l/min = 0.017l/sec<br>1 bar = 10.2m head pressure |

To specify the correct pipe diameter for the header main, you need to calculate the friction losses (or head loss) in the supply lines. This is calculated using a nomogram (figure 5). Nomograms are available from pipe suppliers and vary depending on the material of the pipe.
It is important to correctly calculate friction loss for the pipe diameter and other restrictions, such as bends, so that you can be certain sufficient delivery pressure can be achieved at the point of discharge.

Continuing with the example for growing pigs above, where the required pressure at the nipple drinker is two bar.

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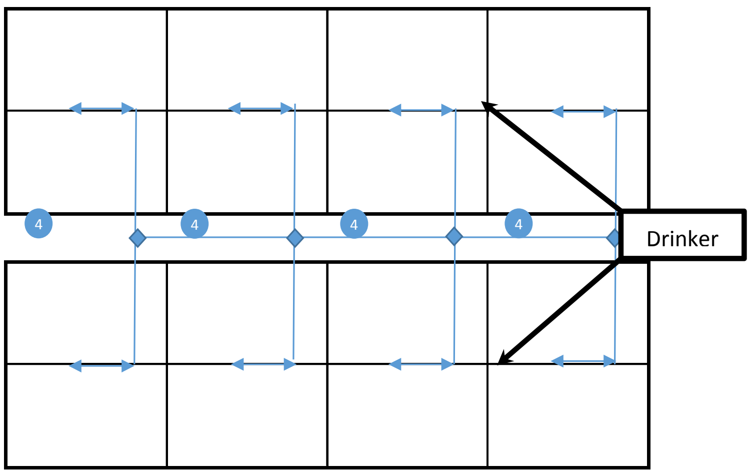
**Determining Pipe Diameters – Rearing House Example**

Figure 3: Layout 2 – Rearing house




Using the figures from the previous stages, the required pressure for each lateral is 20.4 m head or 2 bar (see Table 5) and the required flow is 4 .8L/min.

As shown in Layout 2, the drinker laterals are arranged in four sets of pairs fed through double saddles on the main. Each lateral has a maximum demand of 4.8 L/min (or 0.082L/sec) divided by the number of supply points (not drinkers).
Thus, at each double saddle the required flow rate is 9.6L/min (or 0.164L/sec).

For this example, the distance between each take-off point (double saddle) is 12 m.

Now use the nomogram (figure 5) attached at the end of the document to calculate friction/head loss at each point.

Table 6: Calculation of pipe friction loss for 32mm pipe

| **Pipe Diameter 32mm** | | | | |
|---|---|---|---|---|
| | **Flow rate (L/min)** | **Pipe length (m)** | **Friction/head loss (m/100m)** | **Delivery head Loss (m)** |
| | | | | |
| | | A | B | A/100 x B |
| Point 1 | 38.4 | 12 | 2.0 | 0.24 |
| Point 2 | 28.8 | 12 | 0.9 | 0.11 |
| Point 3 | 19.2 | 12 | 0.7 | 0.08 |
| Point 4 | 9.6 | 12 | 0.2 | 0.02 |
| **Total friction loss (m) D** | | | | 0.45 |
| **Drinker lateral pressure requirement (m) E** | | | | 20.4 |
| **Pressure supply required at start of pipe (m) D+ E = F** | | | | 20.85 |

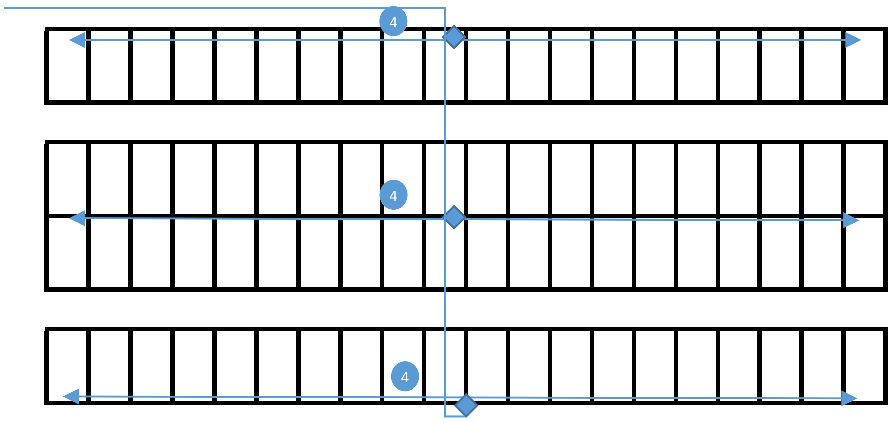
This calculation shows that, using a 32 mm header main feeding four pairs of 2 5 mm, the laterals supply 4.8L/min each at 2 bar design pressure.

The pressure of the main as it enters the building at a point 12 m from the first lateral needs to be 2.85 bar (F in Table ). This performance is within the tolerance necessary to avoid excessive flow differentials between drinkers in the building.

***The pressure–flow specification for this header main is 0.65L/sec at 2.1 bar.***

*Determining Pipe Diameters – Farrowing House Example*

**Figure 4: Layout 3 – Farrowing House**




In this example, the supply must satisfy demand from 80 sows in four rows of pens. The centre rows of pens are placed head-to-head.

The supply at each pen should deliver a minimum flow rate of 2.0L/min (see Table 3).

This can be achieved by selecting a 2 mm orifice at 1 bar pressure. This would actually give a flow rate of 2.1L/min, which is more than sufficient.

**To satisfy welfare requirements, it is assumed that all the sows in the building will be able to drink at the same time.**

Therefore, there should be 10 drinkers (one for each pen), which in this case will be placed at 2 m centres (intervals) along each line.

Each pen will be fed from saddles in the case of each row of pens against a wall, or saddle and tee in the case of the centre double row of pens. However, the use of double saddles should be considered to save on cost.

*Determining the correct pipe diameter for the laterals*

The pipe diameter of the laterals needs to be sufficient to allow the required flow without incurring excessive friction losses. On economic grounds, it is desirable to select the smallest diameter that meets the needs of the installation.

To calculate the friction loss along the lateral feeding of the centre rows of pens, refer to the nomogram (figure 5) attached. The flow volume rate will decrease along the length of the lateral as water is drawn off.

In this example a pipe diameter of 20 mm was selected as a starting point for the calculation.

Table 7: Calculation of friction loss in the centre lateral (pipe diameter 20mm)

| Pipe Diameter 20 (mm) | | | | |
|---|---|---|---|---|
| | **Flow rate (L/min)** | **Pipe length (m)** | **Friction/head loss (m/100m)** | **Delivery head loss (m)** |
| | | | | |
| | | A | B | C = A/100 x B |
| Point 1 | 21 | 2.5 | 4.00 | 0.100 |

| | | | | |
|---|---|---|---|---|
| Point 2 | 18.9 | 2.5 | 3.50 | 0088 |
| Point 3 | 16.8 | 2.5 | 2.50 | 0.063 |
| Point 4 | 14.7 | 2.5 | 1.80 | 0.045 |
| Point 5 | 12.6 | 2.5 | 1.40 | 0.035 |
| Point 6 | 10.5 | 2.5 | 1.10 | 0.028 |
| Point 7 | 8.4 | 2.5 | 0.80 | 0.020 |
| Point 8 | 6.3 | 2.5 | 0.50 | 0.013 |
| Point 9 | 4.2 | 2.5 | 0.30 | 0.008 |
| Point 10 | 2.1 | 2.5 | 0.08 | 0.002 |
| **Total friction loss (m) D** | | | | 0.454 |
| **Drinker line pressure (m) E** | Drinker design pressure (1 bar) | | | 10.200 |
| **Pressure supply required at start of pipe (m) F = D+ E** | | | | 10.654 |

In this calculation, where a 20 mm diameter pipe has been selected for the lateral, the head loss in the pipeline was found to be 4.5% of the line operating pressure, and it is, therefore, acceptable.
The layout of laterals should be designed to minimise the lengths, and the variation in lengths and diameters of pipe runs in the building. The standardisation of the design of elements of the water distribution system reduces the number of types of spares that should be stocked for emergency repairs.
In the above example, the feed to laterals is at the centre of the building, thereby minimising pressure differences along the laterals and allowing a 20 mm diameter pipe to be used as standard throughout the building.
If the supply came from one end of the building, the calculation would show that the 20 mm pipe would be inadequate to cope with the projected demand. In this case, the diameter of the pipe would have to change at least once along the length of the building to minimise friction losses.

*Determining the correct pipe diameter for the supply main*

The calculation for losses in the header main has been carried out using a 50 mm pipe, with the results in the pipework losses being less than 1% of the total operating pressure.

Table 8: Calculation of friction loss in the supply main (50mm pipe diameter)

| **Pipe Diameter 50 (mm)** | | | | |
|---|---|---|---|---|
| | **Flow rate L/min** | **Pipe length (m)** | **riction/head loss (m/100m)** | **Delivery head Loss (m)** |
| | | | | |
| | | A | B | A/100 x B |
| Point 1 | 63.0 | 3 | 0.45 | 0.014 |
| Point 2 | 42.0 | 7 | 0.25 | 0.175 |
| Point 3 | 21.0 | 7 | 0.09 | 0.006 |
| **Total friction Loss (m) D** | | | | 0.195 |
| **Drinker line pressure (m) E** | Supply pressure required for lateral (Table 7 ) | | | 10.654 |
| **Pressure supply required at start of pipe (m) D+ E = F** | | | | 10.849 (10.9) |

***The pressure–flow specification for this header is 1.0L/sec at 2.0 bar.***

**Conclusion**

To feed this system by gravity, the header tank outlet needs to be at least 10.9 m above the height of the drinkers. Therefore, in practice this system would need to be pressurised using a pump.

**REMEMBER: Keep pressure loss in headers to less than 20% of line operating pressure to ensure that all animals can always get the right amount of drinking water.**

## 5. Specify Supply to the Whole Site

Efficient distribution of water around sites is a critical element of good system design. Historically, header tanks have been used in individual buildings; simple calculations show that it is possible to use gravity to supply a building fitted with nipple drinkers using a header tank not less than 2.5 m above the outlets, if you select the correct pipe and drinker combination for the situation.

Where it is not practical to gain sufficient head from a header tank alone—for example, when needing to increase flow in an existing system installed using small diameter pipe—it may be possible to fit a small booster pump immediately after the header tank to ensure good supply to all outlets. The required outlet pressure of the booster can be calculated using the above method.

The final element of water supply design is to calculate the maximum flow requirement for the site, which can be achieved by assembling the pressure–flow specifications of the individual command areas to produce an overall system design.

The total flow required of the system is simply the sum of the flows for each command area.

Thus, the flow requirement for Layout 1 is (38.4 + 38.4 + 63) 139.8L/min (30.7 gallons per minute).

Friction losses in the main distribution pipework should be calculated on a leg-by-leg basis so that pipe diameters can be specified to suit each element of the system.

In this case, the maximum flow rate through 50 mm pipe creates a velocity of about 1.75m/sec, which is approaching the desirable maximum.

If the site layout involved 20 m between buildings and a further 40m to the water source, the flow–pressure relationship at the main supply is calculated as before, using a nomogram (see Table below).

Table 9: Calculating friction loss for 50mm pipe

| **Pipe Diameter 50 (mm)** | | | | |
|---|---|---|---|---|
| | **low rate L/min** | **Pipe length (m)** | **Friction/head loss m/100m)** | **Delivery head loss (m)** |
| | | | | |
| | | A | B | A/100 x B |
| Point 1 | 139.2 | 20 | 1.40 | 0.28 |
| Point 2 | 99.6 | 20 | 0.55 | 0.11 |
| Point 3 | 60 | 20 | 0.50 | 0.10 |
| **Total friction Loss (m) D** | | | | 0.49 |
| **Drinker line pressure (m) E** | | | | 20 |
| **Pressure supply required at start of pipe (m) D+ E = F** | | | | 20.49 |

***The pressure–flow specification for the main supply is 2.32L/sec at 2.4 bar.***

**REMEMBER: When designing a water supply system, consider any expansion of the unit that might be possible, even if it is not anticipated. It is expensive to increase the size of even a short pipe run if it is buried under concrete!**

# 8 Auditing and Improvements to Existing Systems

Carrying out a water audit and preparing a management plan are simple ways to understand and improve water on your farm. You should:

- **Know how much water you are using and what it costs.** This way, you know that the improvements are working. Using meters to record water use around the farm will help identify areas for improvement and tell you when measures implemented have worked.

- **Work out how much water you should be using with standard values.** Compare the industry benchmarks with what you are using, then identify how you can improve on observed performance.

- **Find ways to reduce water use.** Identify and fix leaks, and improve water pressure to reduce poor provision.

- **Prepare a plan to improve water security and efficiency.** Write down ways in which you can make things better and prioritise actions to optimise outcomes.

Existing farm water supply systems often rely on undersized pipes that come with related risks of poor supply at the end of lines, and pump, main or fitting damage associated with high velocities. Problems with these systems are often associated with running pipework at relatively high pressures to overcome supply issues. This results in high velocities in pipework and leaves systems vulnerable to damage by water hammer.

Some supply problems can be simply overcome using quick fixes to reduce losses, such as by moving the end feed on the supply to a house to the middle of the building, or linking the ends of supply laterals across the end of a building to create a circuit using a suitably specified pipeline.

Whilst it is not always possible to undertake a comprehensive review of a farm water supply system and implement necessary or desirable changes, it is important to carry out an early review to identify priority issues, such as addressing risks of microbial contamination and leakage.

# 9 Frequently Asked Questions

Q. CAN I USE BLUE POLYETHYLENE PIPE ABOVE GROUND?

A. Blue plastic pipe is designed for below-ground use; however, it may be used above ground in situations where it is not exposed to light and is protected against:

- undue warming,
- freezing, and
- potential contamination from the environment.

**Where pipe is exposed to light, heat or cold, black polyethylene pipe, manufactured to standards EN 12201-2 or EN 13244-2, should be used in the place of the blue pipe.**

Q. HOW CAN I PROTECT FROM BACK-FLOW?

A. The Water Supply (Water Fittings) Regulations and Scottish Water Byelaws require that the public mains be adequately protected from backflow.

The regulations and byelaws define Fluid Risk Categories by the type of contaminants that may be present, and consider the risk of harm to human health which may be caused – this also applies to pig health. They also specify the appropriate types of prevention devices that must be fitted to guard against backflow.

Back-flow prevention devices must be fitted between the domestic plumbing system and the source of the potential contamination.

The following table describes the fluid categories and typical backflow protection devices that could be used:

Table 10: Fluid categories and backflow prevention measures

| Fluid Category | Description | Risk | Measure |
|---|---|---|---|
| 1 | Drinking water | No risk | No protection |
| 2 | Change in odour, temperature or taste | Slightly unpleasant | Single check valve |
| 3 | Low toxicity chemicals | Slight health hazard | Double check valve |
| 4 | Toxic chemicals or carcinogenic substances | Significant health hazard | Type AF air gap |
| 5 | Faecal and pathogenic organisms | Serious health hazard | Type AA or AB air gap |

Q. CAN A PUMP BE INSTALLED ON A SUPPLY PIPE TO BOOST LOW PRESSURE?

A. Pumps can be installed on supply pipes, but if the pump can deliver more than 12L/min, you must notify your water provider and seek consent before starting work.

Q. DO I NEED TO PROTECT THE WATER SUPPLY FROM BACKFLOW? WHAT IS IT AND HOW DOES IT HAPPEN?

A. The Water Supply (Water Fittings) Regulations and Scottish Water Byelaws require that water or water-using equipment used with fluids or materials that could contaminate must have adequate protection. This protection is to stop potential contaminants getting into other parts of the system, especially drinking water.

Backflow is when fluids travel back towards the source, against the intended direction of flow.

Backflow can happen in one of two ways:

1) Changing water pressure can cause a negative pressure or vacuum in the water supply. This can result in fluids being sucked back into the main system. Fluctuations can happen when repairs are carried out or when there is high demand.

2) Where the pressure downstream is greater than upstream, fluids can be pushed back into other parts of the system.

Once contaminants are in a water system they can be redistributed to other parts of the system and sometimes back into the public mains.

On pig farms, now and in the future, it is important to keep pollutants out of the farm system and medicines out of the public water supply.

Q. WHAT IS THE DIFFERENCE BETWEEN A CHECK VALVE AND A NON-RETURN VALVE?

A. A check valve is designed to prevent backflow. It will have been tested to meet strict criteria, which ensure that fluids are not siphoned back into drinking water systems.

A non-return valve is like a check valve, but cannot meet this strict criterion.

Q. I AM INSTALLING A NEW WATER PIPE, HOW DEEP THE TRENCH SHOULD BE?

A. There are minimum and maximum installation depths:

The minimum depth is 750 mm.

The maximum depth is 1350mm.

If you wish to install the water company's service pipe, either deeper or shallower than these depths, you must ask for permission.

Important note: Gas service pipes should be at 600 mm to ensure separation from water service pipes.

Q. WHO IS RESPONSIBLE FOR PRIVATE WATER SUPPLIES?

A. The Private Water Supplies Regulations set requirements for private supplies. Except for Northern Ireland, Local Authority Environmental Health departments are normally responsible for checking the safety and sufficiency of private water supplies in their area. In Northern Ireland, this is the responsibility of the Drinking Water Inspectorate at the Department of the Environment.

The Water Supply (Water Fittings) Regulations and Scottish Water Byelaws only apply where water is provided from the public supply, including properties with a mains water backup supply. The regulations and byelaws provide a useful code of practice for installation and backflow prevention requirements for private water supplies that will help secure the quality of your private water supply.

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**Figure 5: An example nomogram for PE and uPVC pipes**

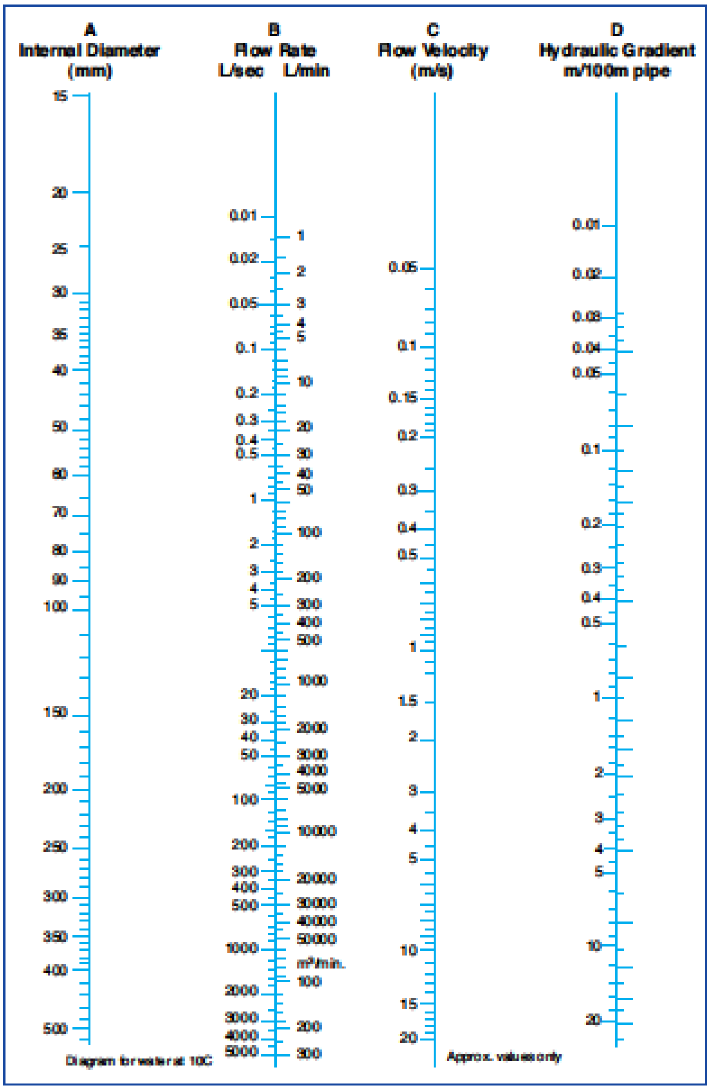
## Pressure Losses and Flows in Polyethylene Water Pipelines

### Flow Calculations for Water

Pressure drop due to friction can be determined for practical purposes using a flow nomogram. The GPS nomogram is based on the Colebrook White formula for water at 10°C using a hydraulic roughness factor K for new pipework of 0.003mm.

The pressure drop at a given flow rate can be determined as follows:

1. Obtain the internal bore diameter of the pipe to be used by referring to the dimensions tables.
2. Mark this diameter on Scale A.
3. Mark the required flow rate on Scale B.
4. Draw a straight line connecting the points on Scales A and B and extend the line to cross Scales C and D.
5. The velocity of flow in metres per second is determined from the intersection with Scale C.
6. The frictional head loss in metres per 100 metres of pipe can then be read off Scale D.




### Flow Nomogram

NOTE: For sizes not covered by the nomogram, please contact our Technical Support Department for further information.

### Fittings

The calculation of pressure drop in fittings is more complex, but calculations can be made for equivalent lengths of straight pipe using the Formula E = F x d where:

E = equivalent pipe length (metres)

F = fittings constant (See opposite)

d = fitting internal diameter (mm)

To calculate the total pressure drop in the system, the equivalent straight pipe lengths for fittings is then added to the total straight pipe length to obtain the total drop.

**Fittings constant**

| Fitting | F |
|---|---|
| 90° Elbow | 0.030 |
| 45° Elbow | 0.015 |
| 90° Tee – Straight through | 0.020 |
| 90° Tee – Side branch | 0.075 |
| 90° Long Radius Bend (4D) | 0.020 |
| 45° Bend Long Radius Bend | 0.010 |
| Reducer (d/D= 3/4) | 0.007 |

# Appendix 5 How to measure flow rates

**Equipment list**

- Graduated plastic jug
- Watch or stopwatch
- Pipe wrench/ monkey wrench
- Pipe grips
- Long nose pliers
- Old toothbrush/ small wire brush
- Spare drinkers
- Plumber's tape (PTFE or thread sealing tape)

**Procedure**

**Water flow rates are best estimated when multiple drinkers are being used at peak demand in late afternoon – aim for 10% of drinkers in use in occupied pens. This flow rate assessment is different to the routine checking and maintenance of drinkers**

- Collect water into the jug for 30 seconds – double this measurement for the flow rate per minute
- Check flow rate of **first** and **last** drinker in the house, which checks for pressure drop along the line
- If the flow rate at any particular drinker is low, remove the drinker head and inspect the filter
- Clean the filter with a backflush of water or air – some filters are quicker to clean if removed from the nipple. Take care that the filter is not damaged if using a brush
- Check the chosen aperture behind the nipple – maybe select a different size?
- Refit, with plumber's tape if required
- Re-check the flow rate once more with a cleaned drinker and filter

**Table 20. Recommended flow rates per stage of production**

| Stage of production | Recommended flow rates (l/min) |
|---|---|
| **Farrowing** | 1.5–2.0 |
| **Weaner** | 0.7 |
| **Grower 1** | 1.0 |
| **Grower 2** | 1.5 |
| **Finisher** | 1.5–2.0 |
| **Dry Sows** | 1.5–2.0 |

*Source: Paragraph 72 of Code of Recommendations for the Welfare of Pigs*


Figure 54. Demonstration of flow rate modifiers found in valve drinkers


Figure 55. Example of bite drinker components

**Remember excessive flow rates will not benefit the pig but may waste water.**

# Appendix 6 Water usage on UK pig farms

Source: Douglas, 2016 (unpublished)

This report, compiled by Farmex Ltd. was commissioned by LMS Ltd. as part of this project to improve the understanding of the current water supply issues on farms across the UK. The report accessed real data from a sub- sample of 30 UK commercial pig units over a 12 month period 2015-2016 where routine environmental monitoring takes place. This report was compiled using the appropriate data to demonstrate how water usage, drinker type, the number of pigs and the various issues encountered with regards to water delivery impacted on the units studied.

The report confirms that there are a large number of variables that contribute towards issues with water delivery on farm, but that through routine monitoring the patterns of water delivery can be used to understand the behaviour of the pigs. The data also demonstrates that the provision of *ad lib* water is necessary to maximise the health and performance of the pigs, but to achieve this there must be a system in place that is fit for purpose.

**Monitoring water flow rates – UK pig units 2016**

Water intake will vary depending on a number of factors; temperature, age, disease, diet, water quality and water flow rate, to name a few. By monitoring the pigs' water usage on a regular basis, variations can be quickly identified and addressed before they become an issue. The following information is derived from an analysis of the latest data available to Farmex from their remote monitoring facilities (Douglas, S., 2016).

Water usage was measured by installed water meters on 30 UK pig sites and recorded using Barn Report. When available, data was analysed from September 1st 2015 to September 2016. In those sites where data was unavailable for the full period (usually because it was a newly monitored site), it was analysed for the period available (Table 1). Data is collected in 15 minute intervals but for the purpose of analysis was aggregated into hourly and daily usage when necessary.

The majority of sites included in the analysis are fan-controlled ventilation systems that operate on a batch basis (Table 1). A small number of sites (3/30) operate on a continuous system, all of which are automatically controlled by natural ventilation systems (ACNV). Pig numbers are recorded on all but one of the sites. 63% of the sites monitored were finishers, 27% were weaners and 10% were farrowing. These numbers are reflective of farm monitoring in the UK, where the majority of sites are the growing herd, in particular finishing pigs.

**Water usage**

Table 2 provides the average daily water usage by production site. The total usage (litres) reflects the total quantity of water used over the time period examined. As expected, the total water usage between sites varies significantly, given the various factors which affect water intake of the pigs as well as the additional uses of water on site (such as cleaning rooms and liquid feeding systems).

Average daily water usage per pig was calculated at those sites where pig number was recorded. Like total water usage, there was a wide range of average daily water usages, particularly in finishing pigs (Figure 1). As water usage rises as pigs age, the greatest average daily water usage was noted for finisher pigs, followed by weaners and lastly by farrowing houses (where water usage includes both sow and piglet intake). While there was a general increase in water usage with increasing pig age, there was a notable decrease in water usage in the first week post-weaning (Figure 2) before it began to recover. This is likely to be a result of the pigs adjusting to their new environment and a reduction in feed and water intake is common, resulting in a 'growth check' that is likely to be caused by the pigs adjusting to their new environment. Some sites appear to suffer this check in water usage more than others (Table 3).

Whilst it would be expected that water usage of finisher pigs would stabilise as pigs near slaughter weight (100kg+), a significant decrease in water usage was noted in the majority of finisher sites towards the end of each batch (Figure 3). It was considered that this may be due to pigs being withdrawn and pig numbers not being updated, but follow-up with sites indicated this does not appear to be the case. Further investigation is therefore needed to establish the causes of this apparent decrease. In contrast, no decrease was apparent in continuous flow finisher systems where the housed population is static, and therefore water usage is consistent with little variation (Figure 4).

In addition to a gradual increase in water usage as pigs age, there is an expected pattern of daily water usage. Although no two sites will be the same, a diurnal pattern of usage should be expected with a peak mid-morning to early afternoon and a decrease through to the middle of the night with usage being close to zero at some point during the night. This pattern is usually established on the first day that finisher pigs enter into a building (Figure 5); however, in weaner pigs there is often no discernible pattern for the first 5 days or so (Figure 6) after which a similar pattern becomes apparent (Figure 7). In farrowing houses there does not seem to be a clear pattern of usage (Figure 8). As piglets will be suckling from the sow approximately every 40-60 minutes it is likely that the sow will be drinking on an infrequent basis when piglets are not suckling.

A happy group of pigs should be in sync and eating and drinking at the same time. If it is difficult to make out a clear pattern (and it is not the beginning or end of a batch) then this suggests their environment may not be optimal. Figure 9 shows an example of a site that had a problem with vice over a prolonged period of time. After some changes were made to the management of the pigs (including pen layout and ventilation), incidence of vice decreased significantly and the daily pattern of water usage became clearer.

Site 11 is a wean-to-finish unit, newly monitored at the time of analysis, so data was only available for a short time period. The average daily water usage at this site therefore reflects that of a weaner pig as the period in question was when pigs were aged 28–92 days of age. In addition, the high average daily water usage observed at Site 18 is likely to be caused by on-site leaks; water usage here was improved by a change in drinker (see below). The lower than expected water usage for

Site 8 can be explained by the fact that the pigs are liquid fed, so only additional drinking water supplied to the room was measured.

**Drinker type**

As water usage reflects both water intake by the pigs as well as wastage, drinker type is likely to have a major impact on on-farm water usage. Nipple drinkers are the most common type used on monitored sites in the UK; however, a growing number of producers are looking to change drinkers with the aim of reducing water wastage while maintaining intake. One such example of this was for site 6 where nipple drinkers were replaced with a bowl drinker (Figure 10).

As a result of installing the bowl drinkers, water usage was significantly reduced and, as a result of measurements taken on farm, it was concluded that there was no negative impact on pigs' performance. A similar change was made on site 18, which is a finisher house (Table 2 and Figure 11). Excessive water usage was evident as a result of water monitoring as well as observations by the production staff about the quantity of slurry being produced.

Old nipple drinkers were removed and replaced with new nipple drinkers that claimed to reduce water wastage by up to 50%. As a result, water usage over the batch almost halved, though whether there is any impact on performance remains to be seen. Pig numbers in each case were the same or similar both before and after the change in drinker type.

**Pig number**

To make sense of water usage both within and between farms, it is important to have a common base unit: water usage per pig. Control units have a 'pig number' setting for this purpose. It is highly recommended that producers keep pig numbers as up to date as possible, particularly in weaners where there can be elevated mortality. Figure 12 shows a good example of a significant decrease in water usage: without pig numbers it might be hypothesised that this was caused by a health or water delivery issue, when in fact it was caused by removal of a large number of pigs from the shed.

**Issues with water delivery and monitoring**

While water monitoring allows us to gain insight into pig behaviour, it also allows detection of faults in the systems and equipment supplying the water. Inevitably, acute equipment failure, such as that causing water leaks, is more visible (both on site and in the data); however, progressive loss of equipment performance is just as important. The ability to regularly capture data also has a major effect on the on the usefulness of that data.

**Internet connection**

Water meters can be read at regular time intervals to ascertain water usage; however, real-time monitoring, which allows automated data analysis, requires an internet connection. For farms, reliable internet access is highly variable and, in some cases, broadband connection is not feasible.

Even once an internet connection has been established, it is all too common for UK farms to suffer from loss of connection for anything from a few minutes to a few days. Table 4 shows that out of 30 monitored sites, 21 sites had up to 1 day per annum with no connection to the internet, a further five units had up to five days of disconnect, and the remaining four sites were disconnected for more than five days per year. One unit had 42 consecutive days without internet access. While the issue on this unit was eventually resolved, the producers were reliant on the telephone company to fix the problem, which meant a significant loss of data in the meantime.

**Water meters**

When installing water meters, it is critical to consider the position of the meters. Standard water meters, which are installed in most commercial pig units, cannot reliably detect low flow rates, so they must be positioned where there is either a sufficient number of pigs, or where pigs are older to ensure that enough water will flow through them. Another consideration is if whether the metered water source will be used for purposes other than just drinking water for the pigs. It is relatively common to see power washing in between batches (Figure 13) and it is easy to identify as we know a batch is not active. However, when the water supply is used during a batch for other things, this can distort the data and give an inaccurate picture.

**Water delivery**

Whether on site or via water monitoring, the effects of an acute failure in water delivery, such as a leak, are usually quickly apparent. As such, these failures are usually dealt with immediately and recurrence is low. During the period covered by the report, only one water leak was reported across all 30 units, and there were no significant outages. There were 29 occurrences of leaks detected by the monitoring systems on 13 units during the one-year monitoring period.

Figure 17 shows an issue that – on first inspection – had all the hallmarks of a dripping drinker or water pipe. However, subsequent inspection of the equipment failed to identify any problems with the equipment on site. Manual observation of the water meter revealed that when the room was empty of pigs but pigs were present in other rooms, pressure was drawing residual water back through the meter. As a result, a non-return valve was fitted after the meter to prevent this recurring.

Progressive loss of equipment performance is a problem that can be difficult to identify because it is often invisible until, over time, marginal changes become more severe. One example is of a reduction in water supply capacity. Over time, blockages in the pipes can reduce the volume and flow rate of water delivered. Figure 18 shows an example of a blocked pipe causing a restriction in water supply; instead of a peak in the data there is a flat line at the maximum value.

**Summary**

Many variables contribute to water usage on pig sites and, as such, water usage across UK sites varies considerably, with no two sites the same. However, continued monitoring of sites allows patterns in water usage to be identified, which can be used alongside on-farm observations to understand more about pig behaviour, as well as about how the water delivery system is functioning. Providing pigs with ad libitum access to water at all stages of production is necessary to maximise the animals' health and performance. Thus, it is sensible to ensure that water delivery systems are fit for purpose and that any problems are rapidly identified and corrected. Several problems were identified as a result of monitoring water delivery on site, and many of these are likely to be present on farms across the UK.

**Table 1.** Description of the 30 monitored pig sites used for analysis

| Site ID | Production Stage | System | Flooring | Ventilation | Data Period |
|---|---|---|---|---|---|
| 1 | Farrowing | Batch | Fully Slatted | Fan | Sep 2015 to Sep 2016 |
| 2 | Farrowing | Batch | Fully Slatted | Fan | Sep 2015 to Sep 2016 |
| 3 | Farrowing | Batch | Fully Slatted | Fan | Sep 2015 to Sep 2016 |
| 4 | Weaner | Batch | Fully Slatted | Fan | Sep 2015 to Sep 2016 |
| 5 | Weaner | Batch | Fully Slatted | Fan | Sep 2015 to Sep 2016 |
| 6 | Weaner | Batch | Fully Slatted | Fan | Jan to Sep 2016 |
| 7 | Weaner | Batch | Fully Slatted | Fan | Sep 2015 to Sep 2016 |
| 8 | Weaner | Batch | Fully Slatted | Fan | Sep 2015 to Sep 2016 |
| 9 | Weaner | Batch | Fully Slatted | Fan | Sep 2015 to Sep 2016 |
| 10 | Weaner | Batch | Fully Slatted | Fan | Sep 2015 to Sep 2016 |
| 12 | Wean to Finish | Batch | Straw Based | ACNV | Dec to Sep 2016 |
| 11 | Finisher | Batch | Fully Slatted | Fan | Jul to Sep 2016 |
| 13 | Finisher | Batch | Fully Slatted | Fan | Sep 2015 to Sep 2016 |
| 14 | Finisher | Batch | Fully Slatted | Fan | Sep 2015 to Sep 2016 |
| 15 | Finisher | Batch | Fully Slatted | Fan | Sep 2015 to Sep 2016 |
| 16 | Finisher | Batch | Fully Slatted | Fan | Nov to Sep 2016 |
| 17 | Finisher | Batch | Fully Slatted | Fan | Oct to Sep 2016 |
| 18 | Finisher | Batch | Straw Based | Fan | Sep 2015 to Sep 2016 |
| 19 | Finisher | Batch | Fully Slatted | Fan | Sep 2015 to Sep 2016 |
| 20 | Finisher | Batch | Fully Slatted | Fan | Sep 2015 to Sep 2016 |
| 21 | Finisher | Batch | Fully Slatted | Fan | Sep 2015 to Sep 2016 |
| 22 | Finisher | Batch | Fully Slatted | Fan | Nov to Sep 2016 |
| 23 | Finisher | Continuous | Straw Based | ACNV | Jul to Oct 2016 |
| 24 | Finisher | Batch | fully Slatted | Fan | Dec 2015 to Sept 2016 |
| 25 | Finisher | Batch | fully Slatted | Fan | Sep 2015 to Sep 2016 |
| 26 | Finisher | Batch | fully Slatted | Fan | Sep 2015 to Sep 2016 |
| 27 | Finisher | Batch | fully Slatted | Fan | Apr to Sep 2016 |
| 28 | Finisher | Continuous | fully Slatted | Fan | Sep 2015 to Sep 2016 |
| 29 | Finisher | Batch | fully Slatted | Fan | Sep 2015 to Sep 2016 |
| 30 | Finisher | Continuous | Straw Based | ACNV | Sep 2015 to Sep 2016 |

Table 2. Calculated Water Usage for 30 UK pig sites

| Site ID | Batch length | Number of pigs | Total Usage, L | Average Water Usage, L/pig | Standard Deviation |
|---|---|---|---|---|---|
| 1 | 35 | 30 | 270510 | 4.50 | 2.11 |
| 2 | 32 | 35 | 41311 | 5.64 | 3.23 |
| 3 | 24 | 144 | 39725 | 0.69 | 0.24 |
| 4 | 61 | 539 | 478953 | 2.89 | 1.56 |
| 5 | 58 | 539 | 565642 | 3.00 | 1.80 |
| 6 | 53 | 352 | 258384 | 2.83 | 1.29 |
| 7 | 70 | 239 | 529210 | 5.96 | 1.83 |
| 8 | 52 | 180 | 61719 | 0.68 | 0.52 |
| 9 | 35 | 329 | 495437 | 4.33 | 2.48 |
| 10 | 34 | 345 | 539859 | 4.02 | 2.39 |
| 12 | 65 | 2000 | 325219 | 1.58 | 0.86 |
| 11 | 126 | 109 | 273988 | 5.18 | 3.04 |
| 13 | 84 | 453 | 883702 | 5.34 | 1.11 |
| 14 | 85 | 251 | 544410 | 5.97 | 1.22 |
| 15 | 88 | 444 | 988647 | 5.48 | 1.49 |
| 16 | 89 | 432 | 752456 | 5.62 | 1.43 |
| 17 | 90 | 210 | 327909 | 5.70 | 1.26 |
| 18 | 95 | 1100 | 4991914 | 14.68 | 5.50 |
| 19 | 93 | 356 | 841264 | 6.03 | 1.76 |
| 20 | 90 | 468 | 518800 | 4.32 | 1.71 |
| 21 | 86 | 456 | 498626 | 5.22 | 1.78 |
| 22 | 100 | 245 | 409058 | 4.67 | 1.50 |
| 23 | - | 1896 | 1397492 | 6.99 | 0.85 |
| 24 | 150 | 155 | 116013 | 6.10 | 3.36 |
| 25 | 82 | 2000 | 3594070 | 5.09 | 1.86 |
| 26 | 60 | 376 | 1036651 | 7.74 | 1.52 |
| 27 | 82 | 346 | 523340 | 3.26 | 1.48 |
| 28 | - | 690 | 7602257 | 11.20 | 4.23 |
| 29 | 85 | 459 | 205623 | 4.10 | 0.94 |
| 30 | - | 179 | 7689280 | 7.22 | 1.14 |

**Table 3. Average Water Usage for weaner sites in the first four weeks post-weaning**

| | | | | Weeks Post-Weaning | | | |
|---|---|---|---|---|---|---|---|
| **Site ID** | **Average** | **Min** | **Max** | 1 | 2 | 3 | 4 |
| 4 | 2.89 | 0.27 | 4.35 | 0.80 | 1.41 | 2.32 | 2.61 |
| 5 | 3.00 | 0.10 | 6.00 | 0.50 | 1.20 | 2.10 | 2.80 |
| 6 | 2.83 | 0.48 | 5.81 | 1.19 | 1.89 | 2.11 | 2.34 |
| 7 | 5.96 | 0.97 | 8.85 | 2.88 | 3.65 | 4.11 | 5.10 |
| 8 | 0.68 | 0.10 | 2.53 | 0.05 | 0.18 | 0.41 | 0.58 |
| 9 | 4.33 | 0.24 | 7.39 | 4.63 | 4.21 | 4.26 | 4.62 |
| 10 | 4.02 | 0.13 | 7.74 | 4.11 | 4.03 | 4.05 | 4.00 |
| 12 | 1.58 | 0.13 | 3.69 | 0.35 | 0.77 | 1.28 | 1.32 |

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Table 4. Data Completion and causes of loss

| Site ID | Internet Connection | Days without internet | No Meter Reset | Data Completion, % |
|---|---|---|---|---|
| 1 | Broadband | 4 | 2 | 98 |
| 2 | Broadband | 0 | 1 | 95 |
| 3 | Broadband | 0 | 0 | 100 |
| 4 | Broadband | 0 | 0 | 100 |
| 5 | Broadband | 0 | 1 | 100 |
| 6 | Cellular | 1 | 2 | 99 |
| 7 | Broadband | 1 | 0 | 100 |
| 8 | Cellular | 0 | 0 | 100 |
| 9 | Broadband | 0 | 0 | 100 |
| 10 | Broadband | 0 | 0 | 100 |
| 12 | Broadband | 0 | 0 | 100 |
| 11 | Broadband | 0 | 0 | 100 |
| 13 | Broadband | 0 | 5 | 99 |
| 14 | Broadband | 22 | 4 | 93 |
| 15 | Broadband | 0 | 12 | 97 |
| 16 | Cellular | 3 | 12 | 95 |
| 17 | Cellular | 0 | 4 | 99 |
| 18 | Broadband | 0 | 0 | 0 |
| 19 | Cellular | 10 | 5 | 96 |
| 20 | Cellular | 0 | 0 | 100 |
| 21 | Cellular | 0 | 0 | 0 |
| 22 | Cellular | 5 | 4 | 97 |
| 23 | Broadband | 0 | 0 | 100 |
| 24 | Broadband | 0 | 1 | 100 |
| 25 | Cellular | 4 | 0 | 99 |
| 26 | Broadband | 0 | 3 | 99 |
| 27 | Broadband | 25 | 8 | 85 |
| 28 | Cellular | 5 | 0 | 99 |
| 29 | Cellular | 1 | 1 | 99 |
| 30 | Broadband | 42 | 0 | 88 |

Table 5. Number of water delivery incidents per site (leaks, drips and outages)

| Site ID | Leaks | Drips | Outages |
|---|---|---|---|
| 1 | 0 | 0 | 0 |
| 2 | 0 | 0 | 0 |
| 3 | 0 | 0 | 0 |
| 4 | 1 | 1 | 0 |
| 5 | 0 | 0 | 0 |
| 6 | 1 | 0 | 0 |
| 7 | 0 | 3 | 0 |
| 8 | 0 | 2 | 0 |
| 9 | 0 | 0 | 0 |
| 10 | 0 | 0 | 0 |
| 12 | 0 | 0 | 0 |
| 11 | 0 | 0 | 0 |
| 13 | 0 | 3 | 0 |
| 14 | 0 | 3 | 0 |
| 15 | 0 | 5 | 0 |
| 16 | 0 | 2 | 0 |
| 17 | 0 | 0 | 0 |
| 18 | 0 | 0 | 0 |
| 19 | 0 | 2 | 0 |
| 20 | 0 | 0 | 0 |
| 21 | 0 | 0 | 0 |
| 22 | 0 | 3 | 0 |
| 23 | 0 | 0 | 0 |
| 24 | 0 | 0 | 0 |
| 25 | 0 | 1 | 0 |
| 26 | 1 | 2 | 0 |
| 27 | 0 | 1 | 0 |
| 28 | 0 | 1 | 0 |
| 29 | 0 | 0 | 0 |
| 30 | 0 | 0 | 0 |

Figure 1. Average daily water usage per pig for finisher units

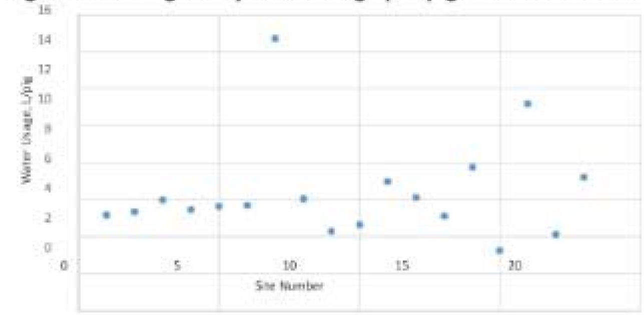



Figure 2. Average daily water usage per pig in the first 14 days post-weaning (site 5)

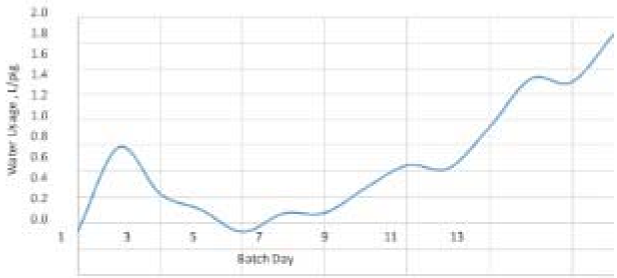


**Figure 3. Average daily water usage per pig for finisher unit (site 14)**

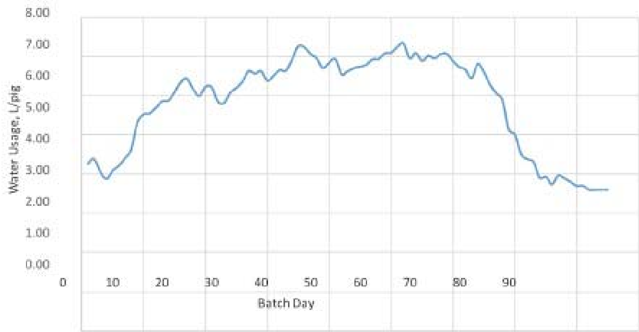



**Figure 4. Total water usage in a continuous finisher system (site 23)**

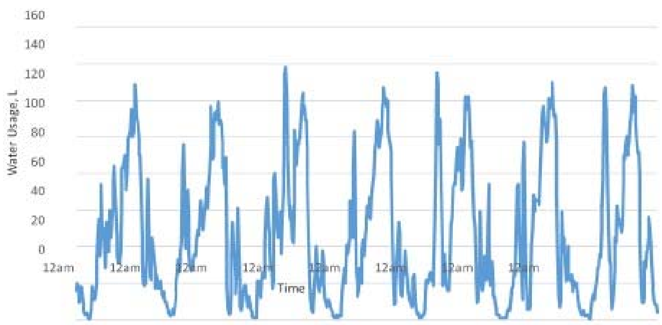


**Figure 5. Total daily water usage in finisher pigs over 3 days (Site 13)**

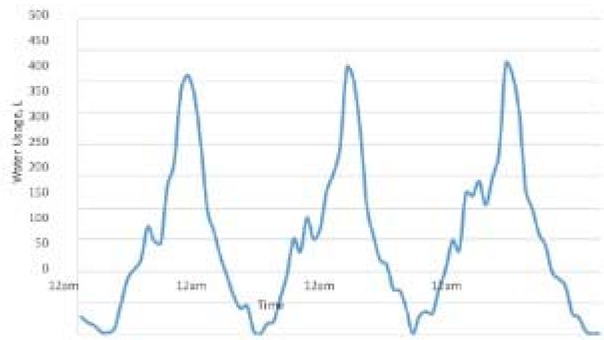



**Figure 6. Water usage per pig in weaner unit for the first 3 days post weaning (Site 7)**

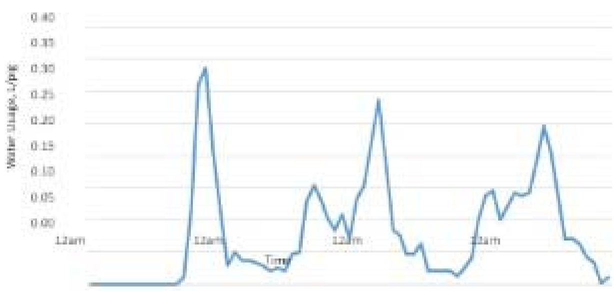


**Figure 7. Daily water usage per pig in weaner unit over 3 days (Site 7)**

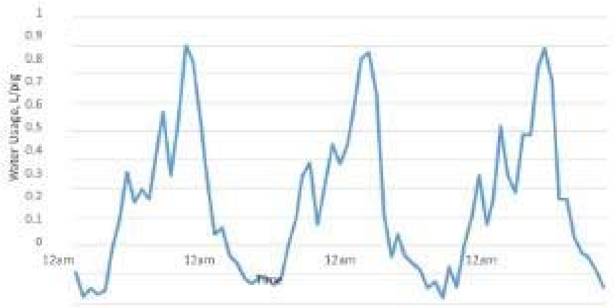


**Figure 8. Total water usage in farrowing house over 3 days (Site 3)**

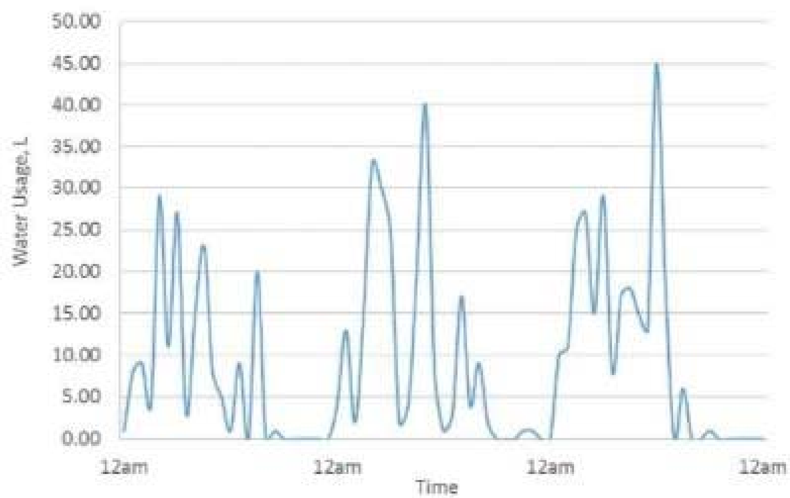


**Figure 9. Total water usage of finisher pigs exhibiting significant vice (site 12)**

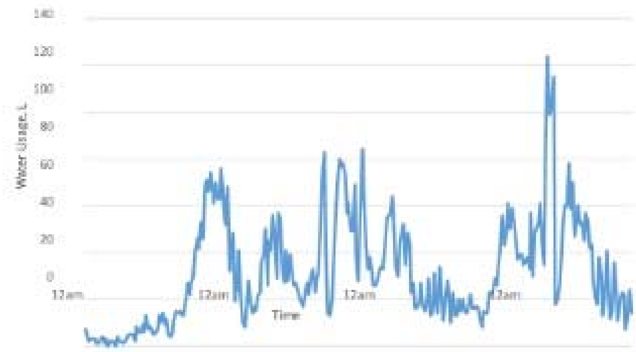



**Figure 10. Comparison of water usage per pig for a weaner site using nipple or bowl drinkers (site 6)**

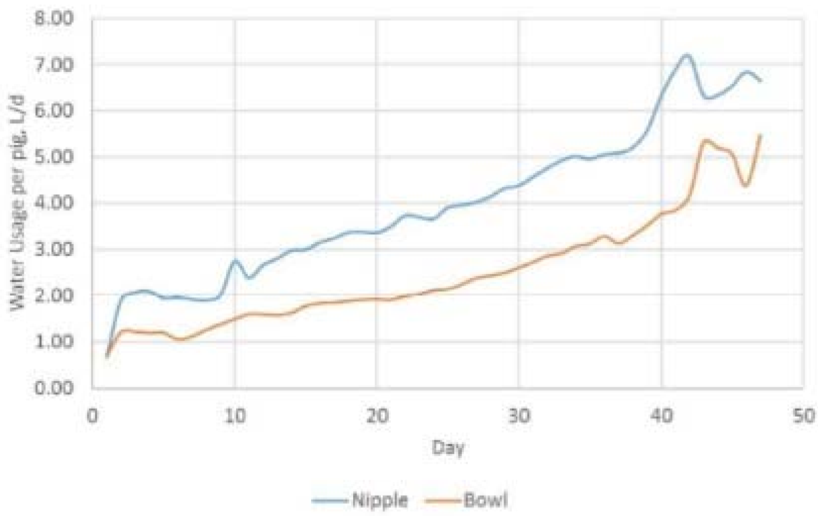


Figure 11. Comparison of water usage per pig for a finisher site with two types of nipple drinkers (Site 18)

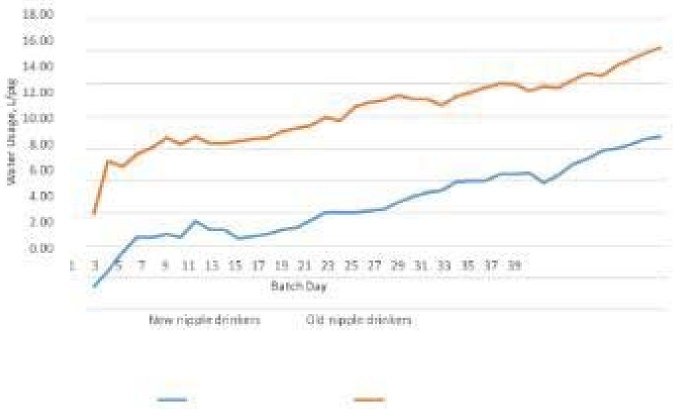



Figure 12. Impact of absence of pig number on total water usage when finisher pigs are removed from a shed (site 24)

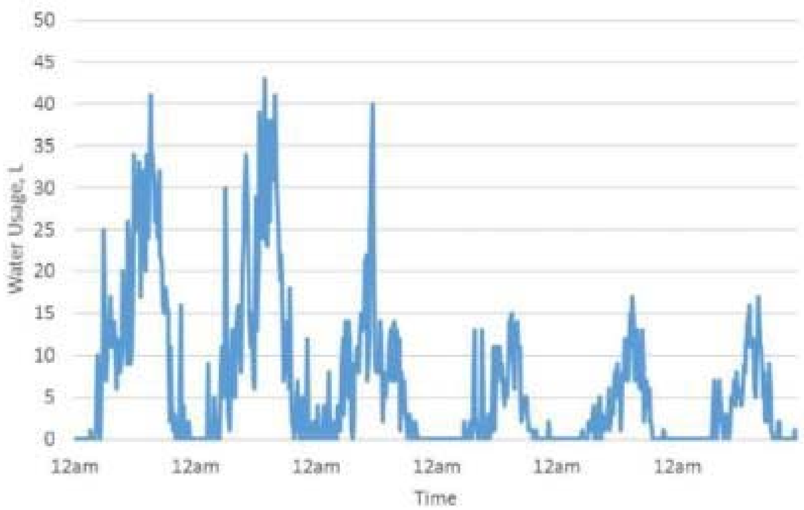


Figure 13. The effect of multiple meter resets on the average daily water usage per pig on a finisher unit (site 15)

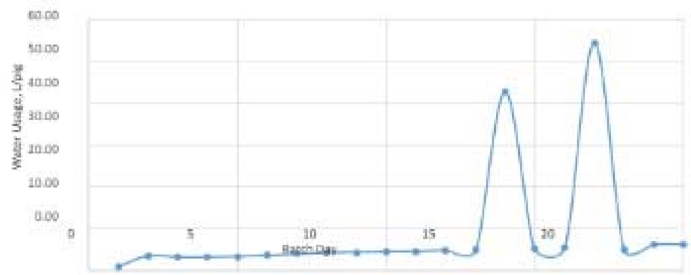



Figure 14. Example of power washing rooms in between batches of pigs on a finisher unit (Site 18)

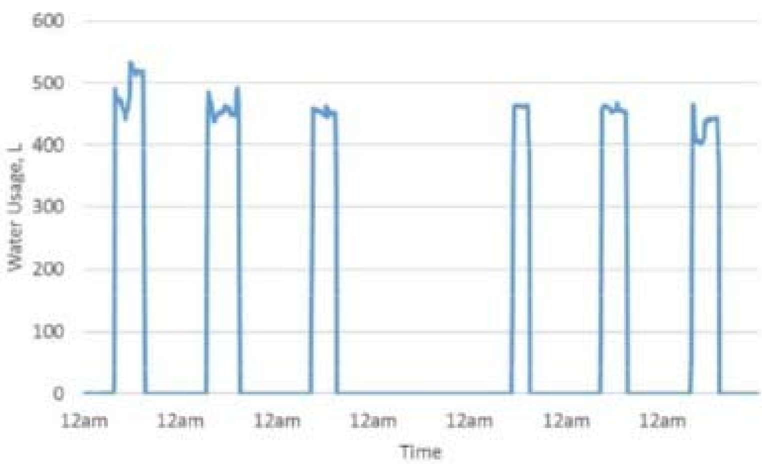


**Figure 15. Suspected water leak in weaner building (Site 5)**

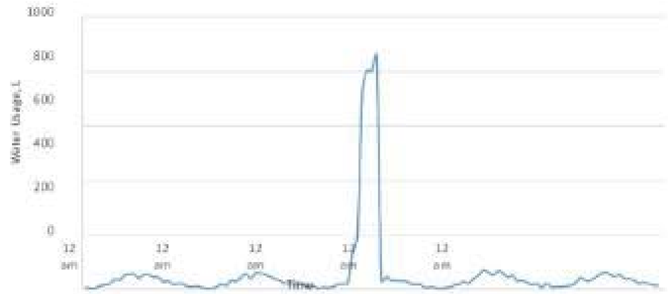



**Figure 16. Example of water drips on a finisher site (Site 25)**

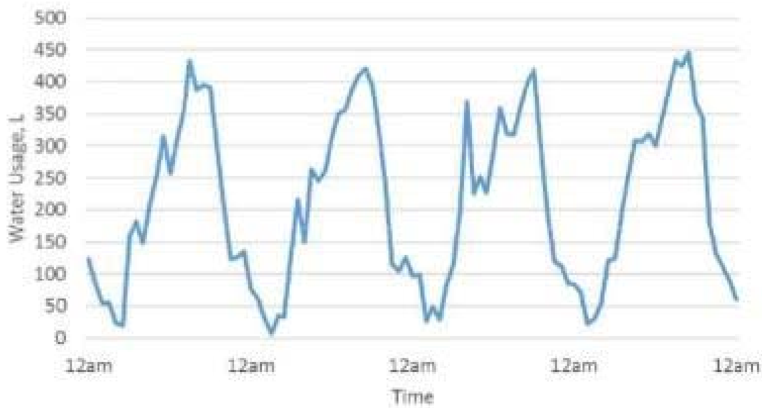


**Figure 17. Example of backflow of water through a meter on a weaner site (Site 7)**

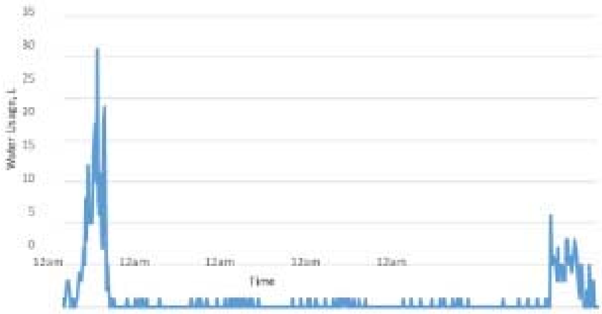
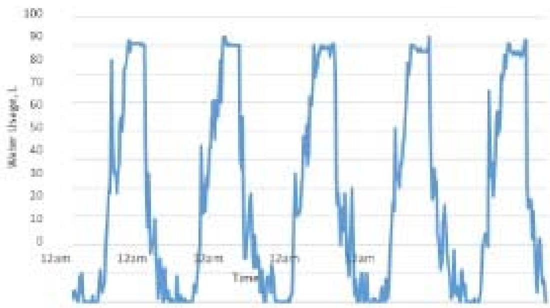



**Figure 18. Limitation of water usage due to a blocked pipe on a finisher site (Site 16)**



## Appendix 7 Example of a calculation of the volume of a water system

When calculating volumes, it is **essential** that you ensure you use the same units.

**Water storage tanks**

The overall volume of this will depend on the size and shape of your tank. The formulae below should be used to help calculate the total volume that a header tank would hold.

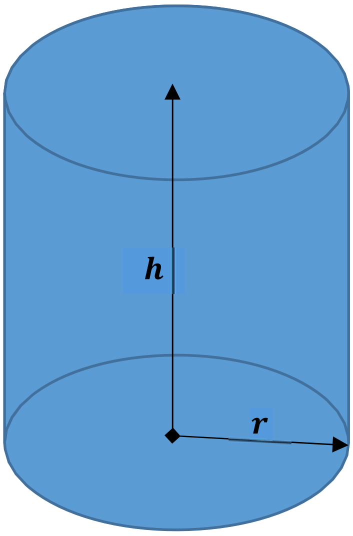
**Cylinder**

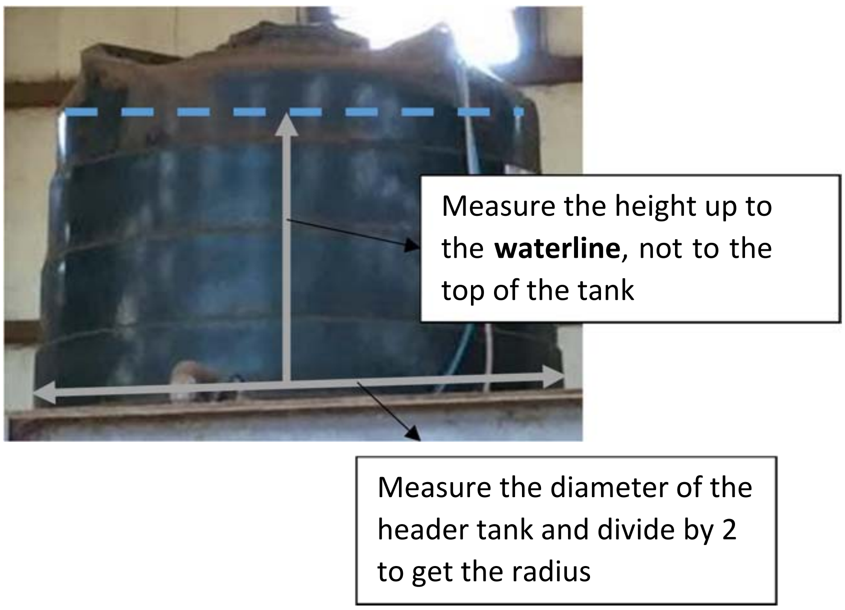
$$v = \pi r^2 h$$

v = volume ($m^3$)

r = radius (internal diameter ÷ 2) of the base of the tank (m), or the midpoint of the tank if not perfectly cylindrical

h = height of the waterline (m)



**Cube**

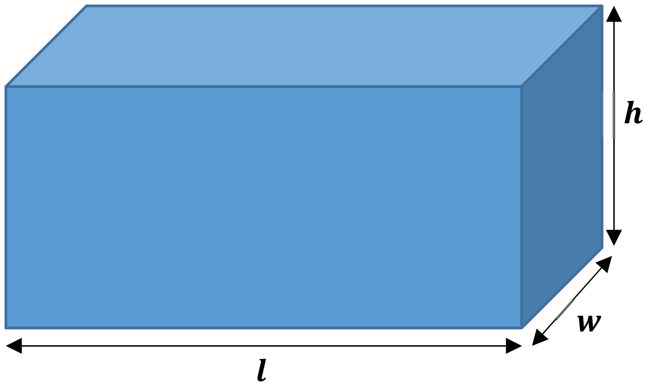
$$v = l \times w \times h$$

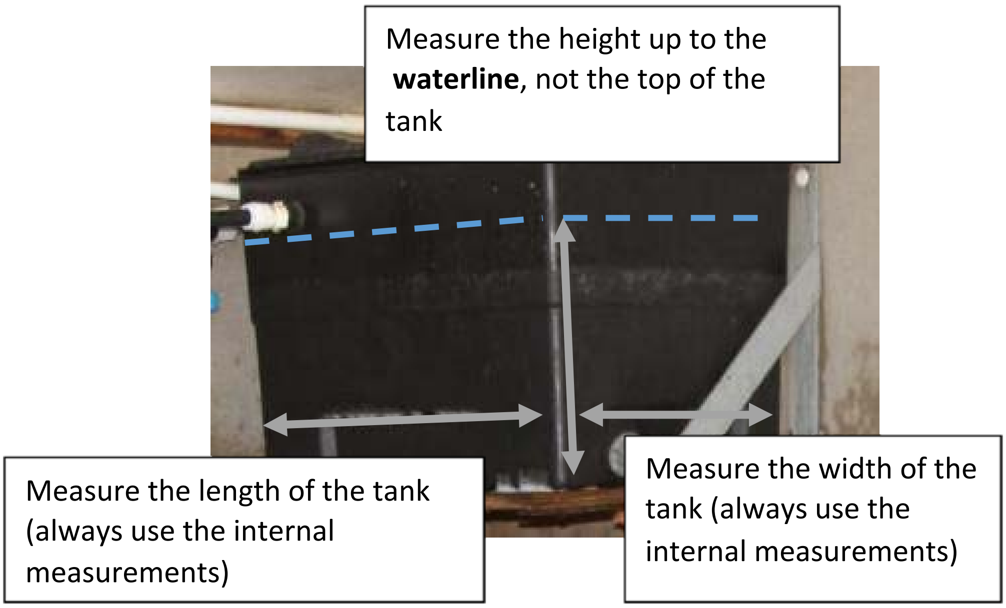
v = volume ($m^3$)

l = length (m)

w = width (m)

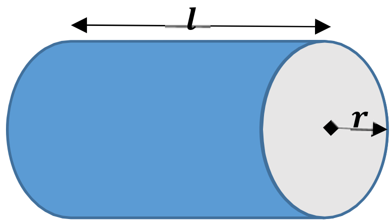
h = height (h)




**Delivery pipework**

It is important that you accurately measure the total length of the delivery pipework to calculate the total circulating volume of water.




$$v = \pi r^2 l$$

v = volume

r = radius (internal diameter ÷ 2) of the end of the pipe

l = total length of the pipework

If there are any areas of different diameter pipework, these must be calculated separately. The substance that the pipes are made out of is not of significance for these calculations, as long as the internal diameters of the pipework are the same. The total length of pipework should include everything, from the outlet from the header tank to the point of connection to the drinker (including the drop-down to the drinker). It is often easier to calculate the drop-down pipes separately, as they may all have the same dimensions.

The example below shows how the total volume could be calculated:

**Header tank volume**

Diameter = 2.4m

Height = 1.82m

$$v = \pi r^2 h$$

v = π x $(2.4/2)^2$ x 1.82

**v = 8.23m³**

**which equals 8,230l Delivery pipework diameter**

<u>Total pipework</u>

Pipe **internal** diameter (see Table 21 below for internal diameter conversions) = 20.2mm = 0.0202m

Length = 100m

$$v = \pi r^2 l$$

v = π x $(0.0202 \div 2)^2$ x 100 v = 0.032$m^3$

<u>Drop-down pipes</u> (set at 1.2m, with 10 drinking points)

Pipe **internal** diameter (see Table 21 for internal diameter conversions) = 20.2mm = 0.0202m

Length = 1.2m

$$v = \pi r^2 l$$

v = π x $(0.0202 \div 2)^2$ x 1.2 x 10 v = 0.0038$m^3$

A calculation table of the volume of water in 1m of each of the commonly used pipe sizes is included below to help with these calculations.

**<u>Total volume</u>**

Total volume = header tank volume + delivery pipe volume + drop-down pipe volume

**Total volume = 8.23 + 0.032 + 0.0038 <u>= 8.27$m^3$ OR 8,266l (rounded up)</u>**

**Table 21. Internal diameter measurements for commonly used drinking pipes and the typical volume found in 1 linear metre of pipe length**

| Material | External Diameter (mm) | Average Internal Diameter* (mm) | Volume of Water in 1 linear metre of pipe |
|---|---|---|---|
| **Blue/black MDPE** | 20 | 15.3 | 0.18 |
| **Blue/black MDPE** | 25 | 20.2 | 0.32 |
| **Blue/black MDPE** | 32 | 25.9 | 0.53 |
| **Black MDPE** | 40 | 34 | 0.91 |
| **Blue/black MDPE** | 50 | 40.6 | 1.29 |
| **Blue/black MDPE** | 63 | 51.2 | 2.06 |

*Internal diameter can vary slightly due to slight variation in wall thickness of the pipe

Water delivery plumbing has the following flow rate capacities:

- 13mm internal diameter pipe of 10l/min
- 19mm internal diameter pipe of 20l/min
- 25mm internal diameter pipe of 35l/min

The above flow rate capacities are only at specified pressure. Water delivery systems must account for pressure (friction) loss in pipes. Pressure loss is the reduction in pressure or 'head' along a pipeline due to the viscosity near the surface of the pipe.

If we use the lower recommended drinking rate of 1l/min for finisher pigs, we can see that every pig drinking at the same time on a water delivery line must be provided with approximately 1l/min. This means that the typical 19mm internal diameter waterline (equivalent to a 25mm external pipe diameter) of a grow-finish building has the capacity for no more than 20 drinking devices. If more devices are installed, the possibility exists that one or more devices will have a limited flow at some point when each drinker is utilised (Brumm, 2009).

## Appendix 8 Dilution rates of specific disinfectants on a range of porcine disease organisms with low organic contamination applied at 10$^{o}$C ambient conditions, contact time 60 minutes *Source: Thomson et al. 2007*

| Active Compound | Recommended dilution range | Dilution rates for target organisms (see reference list below*) | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | APP | BB | PM | HP | SH | SS | ST(1) | ST(2) | ST(3) | BH | SD | YE | EC(A) | EC(T) |
| Iodine (acidic-based) | 1:125-1:600 | 1/1,000 | 1/400 | 1/1,000 | 1/1,000 | 1/800 | 1/1,000 | Not effective | Not effective | Not effective | 1/800 | Not effective | Not effective | Not effective | 1/400 |
| Gluteraldehyde plus quaternary ammonium | 1:150-1:190 (SVD 1:250) | 1/200 | 1/200 | 1/200 | 1/1,000 | 1/200 | 1/800 | Not effective | Not effective | Not effective | 1/800 | Not effective | Not effective | Not effective | 1/800 |
| Peracetic acid plus hydrogen peroxide | 1:100-1:200 | 1/1,000 | 1/200 | Not effective | 1/100 | 1/100 | 1/200 | 1/100 | 1/100 | 1/100 | 1/1,000 | 1/100 | Not effective | Not effective | 1/1,000 |
| Iodine | 1:200 | 1/100 | 1/400 | Not effective | 1/100 | Not effective | 1/200 | Not effective | Not effective | Not effective | 1/200 | Not effective | Not effective | Not effective | 1/400 |
| Quarternary ammonium plus hydrogen peroxide | 1:100-1:200 | 1/10,000 | 1/1,000 | 1/5,000 | 1/400 | 1/100 | 1/1,000 | 1/100 | Not effective | Not effective | 1/800 | 1/100 | Not effective | 1/200 | 1/800 |
| Quarternary ammonium | 1:50-1:100 | Not effective | 1/200 | 1/100 | 1/800 | 1/100 | 1/800 | Not effective | Not effective | Not effective | 1/800 | Not effective | Not effective | Not effective | 1/800 |
| Peroxygen | 1:100-1:200 | 1/800 | 1/100 | Not effective | 1/5,000 | Not effective | 1/200 | Not effective | Not effective | Not effective | 1/200 | Not effective | Not effective | Not effective | 1/100 |

*__APP__ – *Actinobacillus pleuropneumonia*, __BB__ – *Bordatella bronchiseptica*, __PM__ – *Pasturella multocida*, __HP__ – *Haemophilus parasuis*, __SH__ – *Staphylococcus hyicus*, __SS__ – *Streptococcus suis*, __ST(1-3)__ – *Salmonella enterica* Typhimurium (1-3), __BH__ – *Brachyspira hyodysenteriae*, __SD__ – *Salmonella Dublin*, __YE__ – *Yersinia entericolitica*, __EC(A)__ – *E. coli* (Abbotstown strain ), __EC(T)__ – *E. coli* NCTC

## Appendix 9 Water costings (costs stated were correct at the time of publication)

Clean water is valuable because it can deliver benefits to the pigs and to the business of food production. The evidence suggests that most UK pig units already invest in effective water delivery systems, or need to invest to ensure clean water delivery. Changes facing the industry also suggest that investment in clean water delivery systems can promote better health and improve the delivery of nutrients and medications.

Financial benefits depend on the current status of the target pigs, but lifting productivity by 10g/day, 30g/day, or 50g/day would give a gain of 1,250kg LW, 3,750kg LW, or 6,250kg LW per 1,000 pigs finished respectively (at 125 days in the rearing to finishing herd). Thus the cost of maintaining or upgrading a water delivery system needs to be balanced against realistic benefits.

Table 22 below summarises the relative costs and capacities of different water supply systems for livestock, from a Cumbria Farmer Network NW Livestock Programme demonstration event (2012) NWHLI farm project in Cumbria. The range of costs are wide but the annual running costs need to be set against typical mains water costs of £1.25/$m^3$. The costs and capacities are from project data; higher capacity boreholes are not unusual, subject to abstraction licences.

**Table 22. Relative costs and capacities of different water supply systems: demonstration project**

| Method | Average Capital cost | Capacity $m^3$ pa | Total annual cost (£) | £/ $m^3$ |
|---|---|---|---|---|
| Borehole | £2,500<br>£25,000 | 4,000–20,000 | £950–£3,800 | 0.35–0.88 |
| Pasture pump | £350 | 510 | £105 | 0.10–0.15 |
| Ram pump | £250–£2,500 | 750–2,750 | £75–£300 | 0.30 0.85 |
| PV/wind | £1,100 | 1,325 | £450 | 0.35 |
| Water capture | £5,500 | 1,040 | £525 | 0.92 |

http://farmnw.co.uk/news/sustainable_water_systems_demo_event_report_boreholes_pasture_pu

The subject of alternative water supplies is amply covered by the Defra project WU0132 Sustainable Water for Livestock, delivered by ADAS. The report reminds us that while there are no specific legal requirements concerning quality of livestock water, there is plenty of practical farm experience from the UK and abroad to guide competent off-mains water for livestock. Their final report also includes a summary of the pros and cons of alternative forms of water supply.

The costs behind upgrading an existing water supply system on farm will be unique to each farm. The report included in Appendix 4 demonstrates how the hardware on farm can be assessed to see if it is even capable of supplying required water flows to the pigs. The cost calculator shown in Table 23 can be used to create typical capital costs to upgrade an existing room or building.

Thereafter the financial cost of purchasing water-sanitising equipment and consumables will again be highly variable, although a commercial supplier into the UK pig sector is reported as having delivered a system for £1,500 capital and 70p/pig consumables (Kirk, 2016), set against a much larger improvement in growth rates and financial returns. The return on investment is excellent, and any reduction in the requirement for medication for pigs with chronic health issues will be a significant and further benefit. Clean water delivery around a pig unit is a good business target.

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# Table 23 Hardware cost calculator for drinker systems

| PLUMBING GOODS | | UNIT | COST | TOTAL | DRINKERS | UNIT | COST | TOTAL |
|---|---|---|---|---|---|---|---|---|
| | **PVC storage tank and valve** | | | | **Nipple drinkers** | | | |
| | 225 l | | 85.00 | 0.00 | Piglets | | 2.00 | 0.00 |
| | 3,000 l | | 264.00 | 0.00 | Weaners | | 4.92 | 0.00 |
| | **Polythene pipe and fittings** | | | | Growers | | 4.80 | 0.00 |
| | **pipe** | | | | Finishers | | 5.47 | 0.00 |
| | 20mm | | 0.44 | 0.00 | Dry sows | | 5.47 | 0.00 |
| | 25mm | | 0.49 | 0.00 | | | | |
| | **Straight coupling** | | | | **Drinking bowls** | | | |
| | 20mm | | 2.60 | 0.00 | Tongue type | | 31.00 | 0.00 |
| | 25mm | | 3.00 | 0.00 | DRIK-O-MAT mini | | 19.95 | 0.00 |
| | **Bent coupling** | | | | DRIK-O-MAT maxi | | 25.72 | 0.00 |
| | 20mm | | 2.75 | 0.00 | S/S Fordham type | | 36.00 | 0.00 |
| | 25mm | | 4.00 | 0.00 | | | | 0.00 |
| | **Tee piece** | | | | ***Water trough*** | | | |
| | 20mm | | 3.65 | 0.00 | Galvanised | | | |
| | 25mm | | 5.75 | 0.00 | 1.25m long | | 71.00 | 0.00 |
| | **Pipe clips** | | | | 1.85m long | | 105.00 | 0.00 |
| | 20mm | | 0.07 | 0.00 | | | | |
| | 25mm | | 0.08 | 0.00 | | | | |
| | **Stop-cock** | | | | | | | |
| | 20mm | | 6.20 | 0.00 | | | | |
| | 25mm | | 10.80 | 0.00 | | | | |
| | **Tap with rough and coupling** | | 6.20 | 0.00 | | | | |
| | **PLUMBING GOODS** | **TOTAL COST** | | **0.00** | **DRINKERS** | **TOTAL COST** | | **0.00** |

PRICES ARE HIGHLY VARIABLE DEPENDING ON QUALITY AND QUANTITY ~ USE THE SPREADSHEET TO COST PROJECTS

| WATER SUPPLY | | | | | UNIT | COST/m | TOTAL |
|---|---|---|---|---|---|---|---|
| | **Water supply and fittings** | First 150m – materials only | | | | 1.35 | 0.00 |
| | | After 150m – materials only | | | | 1.10 | 0.00 |
| | Installation | Above floors in buildings | | | | 0.87 | 0.00 |
| | | Underground in yards and buildings | | | | 2.10 | 0.00 |
| | | Underground outside yards | | | | 1.70 | 0.00 |
| | | Underground (trenchless method) | | | | 0.47 | 0.00 |
| | **Storage tank** | Reinforced | Reinforced | | UNIT | COST/m³ | TOTAL |
| | | blockwork | concrete | | /m³ | | |
| | First 4m³ | £108/m³ | 166/m³ | | | | 0 |
| | Next 20m³ | £91/m³ | 144/m³ | | | | 0 |
| | Thereafter, depending on internal width | £24.10-48.9/m³ | £40.3-82.0/m³ | | | | 0 |
| | Cover, reinforced concrete or steel | | | per m² | | 52 | 0 |
| | Cast iron inspection cover and frame | | | cost each | | 89 | 0 |
| | Ball valve and float | | | cost each | | 33.9 | 0 |
| | Tank air vent | | | cost each | | 13.2 | 0 |
| | | | | **WATER SUPPLY** | **TOTAL COST** | | **0.00** |

# Appendix 10 Cleaning water systems – Health and safety considerations

All products used in the cleaning and disinfection processes of a water system have the potential to cause harm. It is therefore vital that you:

- Consult the product specification sheet to ensure that the product is used in a safe and appropriate manner
- Develop any necessary control measures to ensure safe working with the product
- Do NOT mix the product with others, unless specifically expressed from the product manufacturer
- Follow necessary COSHH regulations to ensure safe working

The most common type of water sanitiser is sodium hypochlorite (bleach), although there are many different chemicals in use. Most of these chemicals are irritants and, at the higher concentrations seen at the point of purchase, ie before dilution, can be harmful to health. The same applies for organic acids added to drinker systems. All these products can release gases and also cause burns.

It is both good practice and a legal requirement for all staff to be trained and competent in the handling of chemicals. Product information is freely available on COSHH data sheets that will specify the risks and the means for minimising those risks, such as appropriate personal protective clothing.

Know what to do with spillages. For hypochlorite, small spillages can be flushed away with water or absorbed with sand. The most hazardous predictable situations while using cleaning products on water systems in piggeries are:

1. **Localised splashes** with contact to skin and eyes: always wear rubber, vinyl or nitryl gloves and eye protection (goggles; not just safety glasses).
   Always wear eye protection if wearing contact lenses and handling chemicals.
2. **Lifting cleaning products or organic acids** above shoulder height to put chemicals into header tanks, for example.
   The increased risk of chemicals getting in contact with the eyes can be reduced by different filling methods and wearing a protective fullface shield
3. **Mixing/using chemicals in a confined space**
   a) Don't! Mix elsewhere
   b) Provide added ventilation
   c) Wear N95 respiratory protection, suitable for very short-term exposure only to nuisance levels of organic acids

**First aid measures**

| | |
|---|---|
| Eyes | Bathe with running water for 10 minutes, keeping eyelids open |
| Skin | Drench with water |
| Ingestion | Drink 1 cup of water every 10 minutes to dilute in stomach |
| Inhalation | Remove from exposure |

**SEEK MEDICAL ADVICE IF SYMPTONS PERSIST**

It is of interest to note the advice of the Concrete Society on the subject of cleaning products:

"When hypochlorite is used as a sanitizer (as chlorine compounds such as Calcium Hypochlorite and Lithium Hypochlorite, both granular, and the liquid Sodium Hypochlorite), they release Hypochlorous Acid in contact with water, to produce the active sanitizing agent.

Sodium hypochlorite is strongly alkaline; in concentrated form it will attack concrete slowly. Sodium Hydroxide (caustic soda), another sanitizer, up to 10% is not harmful to concrete but at higher concentrations may cause damage by crystallisation and subsequent spalling.

Hydrochloric acid is used as a pH balancer. It is very aggressive to cement-based materials and measures must be taken to minimise concrete damage in the event of spillage.

Sodium Bisulphate is a granular form of acid, used to counteract a scaling condition by lowering pH and/or alkalinity. Sodium bisulphate is acidic but less aggressive than hydrochloric acid – it will cause concrete to disintegrate – and measures must be taken to minimise concrete damage in the event of spillage."

Common sanitizers can attack concrete: imagine what they can do to skin, eyes and lungs

Concrete Society (http://www.concrete.org.uk/)

If in doubt following exposure that could compromise health

**ALWAYS SEEK MEDICAL ATTENTION AS A PRIORITY**

# Appendix 11 Example of a 'shock' water clean-up protocol suitable for an empty room or paddock

'Shock' treatment of water supplies is for discrete water supply lines of known location into empty rooms only

**If supplied by header tank**

1. Turn off, drain, and disconnect the header tank. Inspect and pressure-wash inside the tank to remove gross spoilage and sediment. Reconnect header tank and refill. Turn off supply to header tank once more
2. Fill header tank with suitable steriliser at the correct concentration for the volume of the system supplied, following manufacturer's advice on 'shock' treatment. Suitability will depend on the degree of limescale or biofilm present
3. Flush through the supply water pipes with a high flow rate that helps dislodge biofilm. A flush valve at the end of the main line is helpful in obtaining high flow rates through the horizontal pipe runs. Introduce sanitiser to each drop pipe and fill each drinker/bowl/ trough with sanitiser
4. Leave the system for a minimum four hours or according to manufacturer's instruction
5. Flush the main line once more to remove freed solids
6. Empty header tank of sanitiser
7. Turn on water supply to header tank. Flush clean water through system, checking each drinker for flow and emptying sanitiser from drinking points to avoid taint. Ensure each filter is clean of debris

**If supplied by pressurised system**

1. A permanent water loop bypass system is needed per room, which allows installation of a proportional pump to add the recommended 'shock' concentration of chemical water steriliser
2. Turn off untreated supply to the empty room – divert supply via pump
3. Install and prime the proportional pump
4. Flush the main horizontal pipe run with treated water
5. Fill each drop pipe and drinker/bowl/trough with treated water
6. Leave system filled with sanitiser for a minimum of four hours or according to manufacturer's instruction
7. Restore clean water supply
8. Flush pipes with clean water and check flow at each drinker. Ensure filter at each drinker is free of debris

## Appendix 12 Concentration and conversion tables

Table 24 Comparative concentrations commonly used

| % | PPM | g/l | mg/l |
|---|---|---|---|
| 0.1 | 1,000 | 1 | 1,000 |
| 0.2 | 2,000 | 2 | 2,000 |
| 0.3 | 3,000 | 3 | 3,000 |
| 0.5 | 5,000 | 5 | 5,000 |
| 1.0 | 10,000 | 10 | 10,000 |
| 2.0 | 20,000 | 20 | 20,000 |
| 5.0 | 50,000 | 50 | 50,000 |
| 10.0 | 100,000 | 100 | 100,000 |

Table 25 Factors to allow conversion of commonly used measures of volume and concentration

| From | To | Conversion factor | Example |
|---|---|---|---|
| Gallon (G) | Litre (l) | 4.54 | 1G = 4.54l |
| Millilitre (ml) | Litre | 1000 | 1000ml = 1l |
| Gallon | Millilitre | 4546 | 1G = 4,546ml |
| Cubic Meter ($m^3$) | Litre | 1,000 | $1m^3$ = 1,000l |
| Cubic Meter | Gallon | 219.9 | $1m^3$ = 219.9G |
| Grams (g) | Milligrams (mg) | 0.001 | 1g = 1,000mg |
| % | Parts per million (ppm) | 10,000 | 10% = 100,000 ppm |
| Parts per million | Milligrams per millilitre (mg/ml) | 0.001 | 1,000ppm = 1mg/ml |
| Parts per million | Milligrams per litre (mg/l) | 1 | 1ppm = 1mg/l |
| Bar | Pound force per Square Inch (psi) | 14.5 | 1Bar = 14.5psi |
| Pound force per Square Inch | Bar | 0.069 | 1psi = 0.069Bar |

Appendix 13 Farm case studies

CASE STUDY 1: UNIT EXPANSION WITHOUT CONSIDERATION FOR INFRASTRUCTURE

This study describes the effects of continued expansion of a pig unit with little regard for additional water requirements and infrastructure. There was insufficient water reserve within the dry sow houses, which led to incorrect flow rates at times of peak demand and caused sows to become frustrated.

This manifested as increased aggression during the key, early pregnancy implantation period, and resulted in a reduced conception rate and corresponding litter size during the heat of summer. Once recognised, the problem was corrected and an improvement of one pig weaned per sow per year was observed.

## Background

The unit concerned is a family owned, farrow-to-finish unit that has developed from 60 sows in the 1970s to a 650-sow unit by 2015. It produces 28 pigs weaned per sow per year and sells 27 pigs per sow per year (i.e. it performs within the top 10% at the time of the study). The unit serves to a three-weekly batch system.

Water was originally mains-supplied but a borehole, created in 2000 to help reduce costs, supplies a large header tank with a pump and a 50,000-litre capacity. This pressurises supply of a ring mains running around the farm, before branching into each pig building.

Farm layout in 2012

Service and dry sows are housed in a single, open-span building (bottom left of photo) with straw yards accommodating approximately 20 sows per pen. Each pen has access to an outside (but covered) dunging passage, where two water bowls are available per pen. Pigs are provided ad lib dry feed at weaning, but all other sows are dump-fed pellets once per day.

## Challenges

Given the close association between pigs' feeding and drinking behaviour, this creates a peak demand for sow watering in the hour after feeding, with the feeders normally dumped sometime between 6:00-7:00am. Each quarter of the sow yards' drinkers are supplied from a reserve header tank with a capacity of approximately 250 litres when full; each therefore supplies six yards and 12 drinkers, which each require 12 litres per minute at peak demand.

By 2014, sow performance had improved, meaning the existing finisher buildings were now starting to be limited by the number of animals that could be finished on the original site. One new finisher building was constructed, followed by another, each holding 700 finishers. Water for these buildings was taken from the same two-inch mains supply line.

Farm layout: Purple circle = borehole tank. Red lines = original ring main. Building outlined in red = dry sow house. Blue blocks = new finisher houses built in 2013 and 2014

During the summer of 2015, it became noticeable that sows in previously-settled groups were behaving more aggressively towards each other; this was attributed to hot weather and the stockperson responsible for the sows being on holiday.

Returns increased in two batches, resulting in a reduced conception rate from the normal 92% to around 80%. Fertility of gilts, housed in a separate yard, was unaltered. Compared with the farm average of 13.5 piglets born alive (BA) per litter, the resultant litter size of the affected sow groups was around one fewer piglet BA.

A similar pattern of presumed seasonal infertility arose the following summer. However, it was noticed that the header tank occasionally ran dry and during hot weather, the demands of the rest of the farm reduced the flow of supply to the dry sow house. In fact, during the critical early-morning period, the flow rate was approximately halved, which was insufficient to maintain water levels in the header tanks.

After feeding, sows were unable to access a drinker that supplied water fast enough, creating competition around drinkers and aggression. The disruption and stress associated with this behaviour affected sows particularly during implantation of early pregnancy, resulting in returns and lowered implantation rates and subsequent litter size. As water provision was only slightly below the ideal, it took some time to notice the problems.

### Activity

Once the problem had been recognised, it was rectified by replacing the smaller header tanks with larger (1000 litre), intermediate bulk containers. However, unit managers were concerned that using the ring main risked dangerous under supply, especially given plans for more building work. Hence, it was decided to replace some of the smaller bore pipes with larger-diameter ones and to provide a completely new supply to the sow house.

Previously, the only way to lay new mains underneath concrete surfaces was to laboriously break/relay concrete and to dig trenches. However, recent advances have made this unnecessary. New, specialist machinery allows pipelines to be bored underneath concrete and entire buildings. With the cost-effective hire of a specialist boring team, this unit was therefore able to replace the necessary pipes in a single day.

Boring machine placing pipe underneath a building

An operator with a detector at the front of the machine directs the borer

Boring operative being directed underneath the sows via mobile phone

CASE STUDY 2: REDUCED FLOW RATES AND POOR PERFORMING PIGS

This study describes how hard borehole water, with a raised iron content, led to a build-up of deposit inside the pipes supplying a unit, which, in turn, became populated with a mixed bacterial biofilm. Specific problems had become apparent, such as decreased growth and increased mortality of weaned pigs. A short-term fix involving sanitising pipes and removing limescale restored water flow and quality. Longer term solutions included a continual treatment at the source and specific water acidification in the weaner accommodation.

Background

This unit is a 650-sow producer with a farrow-to-finish site, with four weekly batches and conventional porcine reproductive and respiratory syndrome (PRRS) positive, enzootic pneumonia (EP) positive production.

The farm borehole has supplied all the farm's needs since the 1980s and apart from a large, surface-mounted reserve tank that was created and a fairly rudimentary initial filtration system, there had been no other treatment for 20 years.

Challenges

In 2012 staff noticed a gradual decline in water flow at the most distant parts of the unit, which showed a slowdown in flow rates; this was most noticeable when tanks took longer to fill during pressure washing. Coincidentally, post-weaning performance had begun to deteriorate: mortality rate doubled from 1% to 2% owing to increased numbers of animals showing no significant signs other than a failure to thrive post-weaning, with histological evidence only of villus atrophy. Some looseness was seen, though not acute scour. Food conversion at this stage was 1.65 from 7–38kg in weight.

Farm layout: Purple circle = borehole position. Red circle = the two first-stage weaner buildings holding pigs from weaning

Activity

Several investigations were begun:

a. Borehole water at source was sampled for mineral and bacterial levels.

   Borehole water proved very hard and with significant iron levels, but the results of bacteriology tests of water samples taken before and after the main storage tank were acceptable

b. Water drunk by the pigs was sampled by breaking the pipe above nipples in first-stage accommodation

Table 1. Results of water quality tests in samples taken from pig drinking water

| | TVC 22 | TVC 37 | Coliforms | *E. coli* |
|---|---|---|---|---|
| Far weaner | 4210/ml | 4320/ml | 8720/100ml | <1 |
| Big weaner | 8600/ml | 9600/ml | 24,000/100ml | <1 |

Table 1 shows the results of tests conducted on these water samples, which demonstrated significant bacteriological contamination after passing through the farm pipeline infrastructure. Some samples may have been contaminated as a result of backflow from the drinkers but the 'main drag' pipelines were also likely to be contaminated.

c. Physical examination of pipes throughout the site revealed that internal build-up of a mineralised and ferrous biofilm had reduced the diameter of the main pipe by half. The rough internal surface and high iron environment influenced the build-up of biofilm.

A joined-up approach to combatting the problem was needed. Merely sanitising the worst affected first-stage accommodation area would have only been a temporary improvement; all factors affecting the poor water hygiene needed to be addressed.

To correct slow flow it was necessary to dissolve the build-up of minerals occurring throughout the whole farm plumbing system; however, drinker blockages would have occurred if done too quickly. A biocidal cleansing agent was also required to prevent bacteria being freed from the biofilm and affecting pigs receiving the contaminated water downstream.

A low-level peracetic acid perfusion was set up via proportional pump on the incoming borehole supply; this was used for six weeks while the internal pipeline deposits were gradually cleared. With hindsight, the producer admits it might have been more cost effective to replace the pipeline with hindsight, but this would have involved extensive excavation and breaking of concrete.

To prevent similar problems from developing in the longer term, the filtered borehole water was sanitised using an iron sedimentation system with back flushable filtration and a continuous chlorine dioxide treatment via a proportional pump.

The new filtration and sanitisation system in place

## Results

The problem of the fading weaners resolved coincidentally with a measured reduction in the total viable count of bacteria in the weaner accommodation water supply. However, periodically, gut-related health problems recurred, thus a liquid organic acid mixture administered through an acid-tolerant proportional doser was used to acidify the water for three weeks during the weaning period.

To date, the post-weaning mortality rate of this area now averages less than 1%, growth rates are in the top third, food conversion efficiency now measures 1.55, with pigs ranging 7–40kg in weight.

However, genetic and nutritional changes have also been made so not all the credit for these improvements can be attributed to the changes in water treatment.

CASE STUDY 3: POOR POST-WEANING PERFORMANCE

This case study describes a farm struggling with post-weaning performance following a viral health challenge where the well-intentioned inclusion of a water-administered additive interacted with pre-existing biofilm. This created a bacterial bloom within pipelines and exacerbated the problem. Immediate sanitation, coupled with a continuing water hygiene regime, has led to much improved mortality rates.

## Background

This conventional health - porcine reproductive and respiratory syndrome (PRRS)-positive, enzootic pneumonia (EP)-positive - weekly farrowing, 1000-sow unit weans approximately 600 weaners per week into traditional first-stage flatdecks where they stay for five weeks until they weigh around 20kg.

## Challenges

The unit had been PRRS-positive for some years but during the winter of 2016–17, the PRRS immunity of the breeding herd became unstable. This resulted in the weaning of PRRS-viraemic animals that were also possibly more susceptible to secondary bacterial challenges. During this period of PRRS challenge, the post-weaning mortality rate increased by 2–3% from 2.5%, with most affected weaners showing looseness and fading.

## Activity

The producer had heard about the effective use of acidified water for post-weaning problems, so they tried supporting pigs with the use of a water-administered acid product. However, this proved to be unsuitable and the manager noticed a build-up of slime in the water in the header tanks. Water samples revealed that the pH of the treated water was only pH6.5.

Table 2. Results of water quality tests in samples taken from pig drinking water

| | TVC 22 | TVC 37 | Coliforms | *E. coli* |
|---|---|---|---|---|
| Pre-cleanse | 12,000/ml | 5200/ml | 32,000/100ml | <1 |

## Results

Bacteriological quality measurements (Table 2) showed extensive bacterial and coliform contamination. Furthermore, pH had not been lowered sufficiently to inhibit the growth of *E. coli* despite the description of the product as an ‘acid’.

The presence of pigs in the contaminated areas necessitated a careful choice of water sanitiser, so a hydrogen peroxide treatment was started to clean header tanks, pipelines and drinkers while they were still in use; this was administered via proportional dosing.

As part of continuing routine processes, header tanks were dropped as rooms became empty and were fully pressure-washed before being reassembled and filled with a 'shock' treatment sanitiser between room occupations.

A correct water acidification treatment was administered for three weeks post-weaning to reduce the pH of drinking water to 4. This will reduce the ability of PRRS virus to survive in water systems between batches and reduce the *E. coli* challenge within the upper small intestines of pigs drinking the acidified water.

Three months after the acute episode, the incidence of fading pigs at weaning has reduced and the present mortality level is 1.5% – better than the figures in the previous 12 months.

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